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THE OIL PALM IN MALAYA.

PREFACE.

This publication has been written with the object of supplying the latest available information on the cultivation of oil palm on a plantation scale in this country.

The cultivation of this new crop, which appears to be particularly suited to the conditions obtaining in Malaya, forms a valuable addition to agricultural industries already well established.

Although only about 10 years have elapsed since planting on a large scale was commenced in this country comparatively rapid progress has been made, the total area planted at the end of 1926 being approximately 12,500 acres. Further areas amounting to 45,000 acres have also been alienated for this crop.

The development of the oil palm has been still more marked in Sumatra, where it is stated that the area now planted exceeds 80,000 acres.

While the cultivation of the oil palm does not present any serious difficulties beyond special organisation and supervision in the harvesting of the fruit, the preparation of palm oil and kernels involves the application of technical knowledge in order to maintain a high standard of quality.

The establishment of this industry on a plantation scale has already proved the possibility of producing, under controlled factory conditions, palm oil of a quality so superior

to the West African oil that the standards used to value the latter are not strictly applicable to the plantation product. It is anticipated that when larger and regular outputs of this high grade oil are available the product will compete not so much with a lower grade palm oil from West Africa as with other high grade oils used primarily for edible purposes.

The authors wish to acknowledge the assistance rendered by those members of the Departmental Staff who have supplied information on various points, especially Mr. A. Sharples, Mycologist, for the section dealing with Diseases and Mr. G. H. Corbett, Entomologist, for describing the Insect Pests.

Thanks are due to all managers of oil palm estates in Selangor, particularly Mr. L. P. Jorgensen of Tennamaram Estate, Batang Berjuntai, for so freely granting permission to visit their estates and supplying the Department with the necessary material for investigation.

The majority of the photographs and line drawings are by Mr. J. N. Milsum, Assistant Agriculturist, to whom thanks are due for having executed this work, also to Mr. F. de la Mare Norris, Agricultural Inspector, Johore, for designing the cover.

F. W. South.
Ag. Secretary for Agriculture,
S.S. and F.M.S.

1st October, 1927.

NOTE.—The information contained in the following article is also being published as Special Bulletin No. 39.

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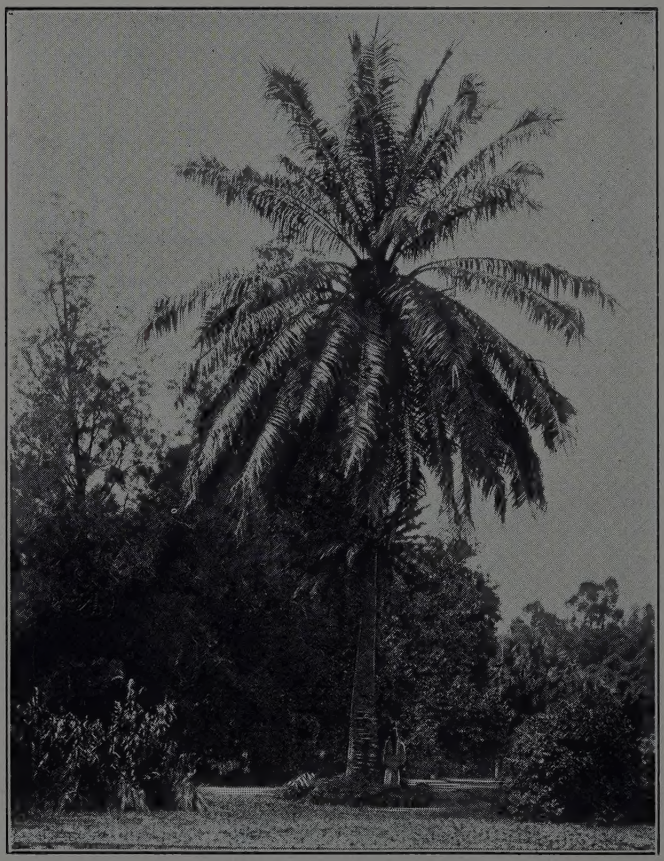


Ornamental Palm, 50 years Old,
in Botanic Gardens, Singapore.

THE OIL PALM IN MALAYA.

B. Bunting, B. J. Eaton and C. D. V. Georgi.

I.—History.

The first record of the introduction of the oil palm, *Elaeis guineensis*, into Malaya is in 1875, when seed was received at the Botanic Gardens, Singapore, from Peradeniya, probably through the Royal Botanic Gardens, Kew. Further supplies of seed were also received from Kew in 1886 and 1887, but many introductions from other sources have been made since these dates.

An attempt was made in 1876 by the late Sir Joseph Hooker to cultivate the oil palm in Labuan. The island of Daat was selected as a suitable locality and from seed sent through the Royal Botanic Gardens, Kew, it is stated that 700 plants were raised. The resulting palms apparently thrived well and fruited, but ten years later were removed in order to make room for coconuts (1).

In 1907 Ridley wrote in the Agricultural Bulletin of the Straits and Federated Malay States, that the tallest palm in the Botanic Gardens, Singapore, stated to be then about 30 years old, was 40 feet high. The height of the trunk, excluding the crown, of the oldest palm remaining in these Gardens is 45 feet, and it is highly probable, therefore, that this is the palm referred to by Ridley, (see *Frontispiece*).

According to the report of the Director of Agriculture, Federated Malay States, for the year 1909 several palms were then in fruit both in the Public Gardens, Kuala Lumpur and the Experimental Plantation, Batu Tiga. Samples of palm oil were prepared and exhibited at the Agri-Horticultural Show at Kuala Lumpur in the same year and were stated to be of good quality.

Further, it is recorded in the above report that seeds of two of the best varieties of oil palm, "Ope pankoro" (hard shelled) and "Orungo" (soft shelled), were obtained from Nigeria and arrived at the end of the year. Some of these seeds were retained by the Department and planted at the Experimental Plantation, Kuala Lumpur, the remainder being distributed to selected estates, widely scattered throughout the country, for trial under different local conditions.

Although the oil palm was introduced into Malaya at such an early date it is significant that it was cultivated only as an ornamental plant for a period of 35 to 40 years, and it was not until the beginning of the last decade, when the world's demand for vegetable oils and fats was increasing to such an extent as to demand additional supplies of these commodities, that any serious attempt was made to cultivate the oil palm in this country on a plantation scale.

The cultivation of the oil palm in Malaya on a plantation scale was commenced during 1917, when an area of land in the district of Kuala Selangor, previously alienated for coconuts, was planted with oil palm. This land was originally allotted to Monsieur H. Fauconnier and formed part of what may be termed the pioneer oil palm plantation of Malaya, now known as Tennamaram Oil Palm Estates.

During 1914 the Department received a number of enquiries regarding the possibilities of cultivating the palm as a plantation crop but, as a result of the war, very little progress was made. The heavy slump in the price of rubber about the end of 1920, however, stimulated interest in the possibilities of the crop.

As a consequence, at the end of 1926 there were no less than nineteen oil palm estates in Malaya, excluding small experimental areas. Of these, one has over 2,000 acres planted, three have between 1,000 and 2,000 acres and five between 400 and 800 acres planted. Three of the above estates had then reached the producing stage.

At the close of 1926 the total area alienated for this crop was 45,322 acres, of which 12,548 acres were planted. The principal planted areas are distributed as follows.— Selangor 9,357 acres, Johore 1,992 acres, Perak 842 acres, Kelantan 200 acres and Negri Sembilan 100 acres.

It may be of interest to record that the Government of the Federated Malay States has provisionally reserved for the cultivation of oil palm additional areas amounting to over 100,000 acres, most of which are situated in Pahang. It is not yet certain, however, whether all these areas will be found suitable for the cultivation of this crop.

The terms and conditions now in force for the alienation of land in the Federated Malay States for the cultivation of oil palm are given in Appendix—A.

The following table shows the exports of oil palm products from the Federated Malay States in recent years:—

Year.	Palm oil.	Palm kernels.
	Tons.	Tons.
1923 ...	195	50
1924 ...	286	81
1925 ...	473	87
1926 ...	726	180

It will be seen from these figures that rapid progress is being made in the development of this new industry and that the oil palm in Malaya may now be definitely regarded as a crop of major importance.

There is no doubt that the palm is particularly suited for cultivation in this country and further there is ample evidence that it grows both quicker and more luxuriantly than in West Africa, which is commonly recognised as its native habitat.

II.—Varieties.

Although numerous varieties of *Elaeis guineensis* have been described from time to time by different authorities, some doubt still exists concerning a correct classification of the various types.

The difficulty of obtaining a definite classification may have been due to the relatively small number of palms grown under controlled conditions, but with systematic cultivation under plantation conditions the problem should be simplified.

Beccari (2) established no less than 18 distinct varieties of oil palms as a result of a critical examination of material collected in the West African Colonies and submitted for examination to the Royal Botanic Gardens, Kew (3).

Jumelle enumerated 19 varieties in reproducing the classification of Beccari and Chevalier. Bücher and Fickendey (4) gave a new classification, and reduced this number to 11, by including 8 varieties described by the previous authors under one heading, but on the other hand they added 8 new varieties to the list, bringing the total again to 19 varieties. Annet (5) considered that this number should be reduced to 7 varieties, two of which might be classified as distinct species.

It is obvious from the above that it is impossible to make any definite classification of the different forms described in the literature cited, until further breeding experiments have been conducted to show to what extent the characteristics are hereditary and which forms are merely hybrids of the original varieties.

From a practical standpoint the most suitable classification is probably according to the thickness of the shell, since the shell is the only useless part of the fruit. A thin-shelled variety is usually characterised by a small nut with a high proportion of pericarp or pulp, such a variety giving the lowest percentage of shell, calculated on the whole fruit.

The development of a type of palm possessing these characteristics is clearly the ultimate aim in the selection and breeding of oil palms.

The selection work carried out so far by the General Experiment Station of the A.V.R.O.S. has been based on these

lines and the following preliminary classification has been suggested by Rutgers and Yampolsky (6):—

A.—*E. guineensis* var. *macrocarya*, the thick-shelled type, the shell being 4 to 8.5 mm. thick and constituting about 50 per cent. by weight of the fruit. The pericarp is thin, varying from 0.75 to 2.5 mm. in thickness. This form is sometimes called the "Congo" type. The kernels are of widely varying dimensions, (see Plate I, fig. 2).

B.—*E. guineensis* var. *dura*, the ordinary type, with a shell from 2 to 5 mm. thick and forming about 30 per cent. by weight of the fruit. The pericarp is thick, varying from 2 to 6 mm. in thickness. This is the ordinary type, commonly called the "Deli" type. The greater proportion of the palms in both Sumatra and Malaya belong to this type. The kernels are of various dimensions, (see Plate I, fig. 1).

C.—*E. guineensis* var. *tenera*, the thin-shelled variety, with a shell from 1 to 2.5 mm. thick and constituting about 10 per cent. by weight of the fruit. The pericarp varies from thick to very thin and the kernels are of varying dimensions. This is known as the "Lisombe" type.

D.—*E. guineensis* var. *pisifera*, the shell-less form. The kernels are very small, about the size of a pea. The pericarp is thick, but the whole fruit is small. This type is probably abnormal.

To the above four varieties might be added the "Mantled" type, the pericarp of which is covered with a mantle of sterile carpels containing oil similar to that found in the pericarp of the other varieties. This type, which is found in the Belgian Congo, is known as the "diwakawaka" form. It also occurs in Nigeria under the name of "Ayara Mbana." The fruit consists of 50 per cent. mantle pulp, 34.5 per cent. pericarp pulp, 11 per cent. shell and 4.5 per cent. kernel. Annet described this type as *Elaeis Poissoni*.

It is interesting to note that trials at the A.V.R.O.S. with four lots of Lisombe seed imported from Africa resulted in the production of a mixture of both good and bad forms. The thick-shelled *macrocarya* was invariably present, and in two instances practically the whole of the offspring was of this form. The common *dura* type was present in varying proportions in all cases. The thin-shelled *tenera* was present

in large numbers in two cases, but barely represented in the other two. The shell-less or *pisifera* type was present in one instance only.

Similar results have been obtained at Buitenzorg, imported seeds always giving a mixture of different forms, the inferior types predominating in several cases.

The results of these trials indicate clearly the inadvisability of planting large areas with imported seed, since the fruit produced from such seed is invariably so mixed as to be considerably inferior to that of the ordinary *dura* type already established in this country. The danger of private individuals importing seed from other countries will therefore be fully realised, introductions of seed being made only after the issue of a permit by the Department of Agriculture.

This Department has recently introduced no less than 40 different lots of seed from the various palm oil producing countries in Africa with a view to obtaining improved types of palms. It is highly probable that a number of these lots will ultimately be found to be of the same type, although introduced under different local names. There is no doubt, however, that this material will form a sound basis for selection and breeding experiments, which it is intended to carry out at the Government Experimental Plantation, Serdang.

In the meantime it is advisable in planting new areas to use only seed of the "Deli" type, which is already well established in the East and is undoubtedly the most stable form of all the desirable types yet examined.

PLATE I.

Fig. 1.

Elaeis Guineensis,
var. Dura,
(thin-shelled type).

Fig. 2.

Elaeis Guineensis,
var. Macrocarya,
(thick-shelled type).

III.—Soils.

The selection of land for the cultivation of oil palms probably requires more careful consideration than for most other tropical crops, since the soil conditions have such a marked influence on the ultimate productivity of the palms.

The lie of the land is also important, the flat and undulating types, which allow of efficient drainage, being naturally more suitable than steep hilly land. The latter, apart from increasing the difficulty of harvesting the fruit, may not provide a sufficient supply of moisture to sustain the palms in full development and at the same time to produce high yields of fruit.

The growth and productivity of the palms depend to a large extent on an abundant rainfall, evenly distributed throughout the year, and also on an ample supply of water in the sub-soil. On the other hand low-lying and badly drained soils are entirely unsuitable.

The roots of the oil palm are naturally restricted by a high water table, but if the land is well drained they will penetrate to a considerable depth. An examination of the root system of several mature oil palms growing on undulating land, with a fairly porous sub-soil, at the Experimental Plantation, Kuala Lumpur, showed that a number of the roots actually penetrated to a depth of between 8 and 10 feet below the surface in their search for both water and food material. Such root development, however, could not possibly occur either in the presence of an impervious clay sub-soil or with a high water table. Efficient drainage of the soil is therefore essential if proper root development is to be encouraged. In fact, on flat land a slightly inferior type of soil with good drainage and free soil water movement will often give better results than a superior type of soil in which the drainage is so bad as to preclude the possibility of proper soil aeration.

The most suitable soil for the oil palm is a loose alluvial loam overlying a friable clay sub-soil, which will not only allow of easy root penetration, but at the same time will permit of the retention of a sufficiency of soil moisture.

Although the oil palm may be grown successfully on gently undulating land, the flat coastal land and inland river

flats, provided they can be properly drained, are likely to give the best results.

Heavy stiff clay, very deep peat, stony laterite and light sandy soils are all unsuitable for the cultivation of this crop.

The heavy stiff clay soils, which tend to cake hard when dry, are unsuitable since they will not permit of good drainage or allow of free root penetration. On the other hand a light friable clay, which when dry crumbles on being touched, is a suitable type of soil.

Deep peaty soils, although usually very rich in humus, are unsuitable principally on account of their loose texture, the acid nature of the soil water and the difficulty of obtaining efficient drainage. On the contrary, shallow peat soils, approximately 4 feet depth of peat, overlying a friable clay sub-soil may be expected to give satisfactory results, providing they are capable of being well drained. With such soils, drainage operations should be carried out well in advance of the planting programme so as to aerate the surface soil and to reduce acidity. The layer of peat will gradually subside until the palms, which incidentally subside with the peat, will after a few years rest on the more permanent layer of clay sub-soil. Several instances of the rapid subsidence of such peaty soil have been observed in the district of Kuala Selangor, where it is not uncommon to see bases of large jungle trees now 2 to 3 feet above the present surface of the soil owing to the drying out of the original layer of surface peat. The palms, which were planted 9 or 10 years ago at the same level as the base of the trees, have gradually subsided with the peat and no roots of the palms are exposed, (see Plate II).

Stony or gravelly laterite soil does not allow of easy root penetration and is therefore unsuitable, although palms may be grown successfully on the loose friable types of lateritic soils, which are frequently found in this country. The latter types of soil permit of both easy root penetration and efficient drainage.

The light sandy types of soils are generally unsatisfactory, since they have not the capacity for retaining a sufficient supply of moisture for the palm, while in addition they are also deficient in the necessary supply of plant foods.

PLATE II.

Subsidence of Palms on Peaty Soil.

The Department proposes to carry out investigations on the growth of oil palms on widely different types of soils with the object of ascertaining the most satisfactory soils for the cultivation of this crop, but it will be realised that some considerable time must elapse before any definite conclusions regarding this problem can be formed.

IV.—Planting.

SEED SELECTION.

The only method of improvement of the oil palm is by seed selection, since vegetative reproduction is not possible.

Variations in the quality of the seed are due to differences in the genetic value of the parent palms. These inheritable factors usually cause considerable alteration in the external character of the palm, although its genetic constitution is often modified by the influence of environmental conditions, thus increasing the difficulty of selecting high grade parents. Before the true value of the genetic characters of such palms can be determined it is necessary to test a number of the offspring under uniform conditions.

Oil palm varieties generally show great variation in their yield of oil. The difference in oil production between different palms is due firstly to the number and size of the bunches and secondly to their composition.

The composition of the bunch affects the yield of oil owing to differences in: —

(*a*) the number and weight of the fruits.

(*b*) the composition of the fruit.

The composition of the fruit may again vary according to: —

(*a*) the percentage of the pericarp and its oil content.

(*b*) the percentage of the kernel and its oil content.

(*c*) the thickness of the shell.

The thickness of the shell has only an indirect influence on the production of oil by either increasing or decreasing the proportions of (*a*) and (*b*) calculated on the weight of the whole fruit.

Apart from the large number of existing varieties of *Elaeis guineensis* classified according to distinct differences in character, it has been shown by Maas (7) that, even within a particular variety such as that cultivated in Sumatra,

there are considerable differences between individual palms, particularly in respect of yield and composition of the fruit.

The form of the individual fruit depends upon the following conditions:—

(*a*) its relative position in the bunch.

(*b*) the number of fruits set in the bunch.

(*c*) the number of kernels within a fruit.

Those fruits formed on the outside of the bunch have more space to develop and are therefore larger and less angular than those in the interior, which are subjected to lateral pressure. Further, the outside fruits containing a single kernel are usually pear-shaped, whilst those with two or more kernels tend to become somewhat spherical.

The above characteristics vary with different types of palms and, until typical specimens of the numerous varieties can be cultivated under the same conditions for some considerable period, it will not be possible to determine those characteristics which are inherent and those which are due to environment.

The variety at present under cultivation in this country, namely *dura*, is undoubtedly satisfactory and, although it shows variation in type with occasional poor forms, this variety should form a sound basis for future work on seed selection.

Since the male and female inflorescences occur on the same palm at different periods, the female flower under natural conditions is fertilised with pollen from another palm and this continuous cross pollination produces eventually a wide variation of types.

In selecting mother palms for future seed supplies only those palms should be considered which produce fruit with a high yield of pericarp containing a high percentage of oil, and such palms should be fertilised artificially with pollen taken from similar high grade parents. At times it may be possible to reserve pollen from a male inflorescence on the same palm, but as pollen cannot usually be kept for long periods such a procedure is not always practicable.

As far as possible seed should be taken only from palms of known parentage, the individual yields of which have been recorded over a number of years. Those palms which produce fruit with a thick shell, with which is usually associated a low yield of pericarp, should therefore be discarded.

This Department has recently introduced seed of a number of varieties from the various palm oil producing countries in West Africa with a view to correlating the different types when grown under local conditions. It is doubtful, however, whether it will be possible to effect by this means any improvement in the type of palm already established in this country, since the *dura* type appears to be superior as regards both percentage of pericarp and oil content.

Attention is frequently being drawn to the possible value of thin-shelled varieties of oil palm, principally as a means of increasing the percentage yield of palm kernels This will be of benefit so long as there is no corresponding diminution in the yield of palm oil, which is from an economic standpoint the principal product of the fruit.

In order to emphasise this point it may be stated that under good plantation conditions, with the existing type of oil palm, a yield of 16 cwts. of palm oil and 4 cwts. of palm kernels per acre per annum may be expected, when the palms are in full bearing. The comparative values of these two products at present prices (September, 1927) are approximately £28 and £4 respectively, which gives a proportion of 7 to 1 in favour of palm oil.

GERMINATION OF SEED.

In the early stages of oil palm cultivation in this country it was found that seed which had been kept for any length of time germinated very slowly. At this period the greater proportion of seed for experimental purposes was being imported from West Africa, and it was usual for such seed to take at least one year to germinate, whilst in certain cases germination only took place after periods of two or three years.

It was discovered later that even fresh seed, from which the oily pericarp had been removed, germinated slowly when

planted in nursery beds composed of ordinary soil, only about 50 per cent. of such seed germinating within a period of 9 months.

The delay and uncertainty of germination proved a serious hindrance from a practical standpoint, especially when a definite planting programme had been arranged, and various experiments (8) were carried out with a view to accelerating germination.

The methods adopted for this purpose included (*a*) soaking the seed in solutions of hydrochloric acid of varying strengths, (*b*) fermenting the seed by placing them in pits filled with alternate layers of manure and seed, (*c*) placing fermented seed for several days in water heated once a day to 40—45°C. and then allowing to cool, and (*d*) planting in open sand beds heavily watered twice a day.

These experiments showed that soaking the seed in acid did not result in any perceptible increase in the rate of germination, while of the three methods depending on the agency of heat the most satisfactory was found to be that of planting the seed in open sand beds. Actual trials with this method resulted in an average germination of approximately 75 per cent. within a period of 16 weeks.

As a result of further experiments carried out at the Government Experimental Plantation, Serdang, (9) it was found that by covering the sand beds with glass frames a slightly higher temperature was developed in the beds, with the result that over 80 per cent. germination was obtained in less than 12 weeks. This simple and practical method of germinating the seeds is so satisfactory that it will probably be adopted in estate practice.

In order to obtain the most rapid germination, seed from fresh ripe fruits only should be used. The seed from unripe fruits or from those fruits which have remained long on the ground should be discarded.

It might be mentioned also that seed from individual palms often shows considerable variation in the rate of germination, which is probably associated with the hardness and thickness of the shell.

PREPARATION OF SEED AND NURSERY BEDS.

As previously stated, fresh seed planted direct in open nursery beds, composed of ordinary soil, gives slow and uncertain germination, so that specially prepared seed beds are necessary in order to accelerate the rate of germination.

Preparation of Seed Beds.—These beds, composed of washed sand about 1 foot deep, are usually placed flush with the ground and fully exposed to the sun. If the beds are shaded germination will be retarded. The sand beds may be of any convenient length, but not more than 5 feet wide, thereby allowing the young seedlings to be removed easily from the centre of the beds. The distance between the beds should not be more than 2 feet, which will be found sufficient for watering the beds and inspecting the seeds.

After the sand beds have been prepared, seed from fully ripe fruits, denuded of the oily pericarp, should be obtained for planting. The seed should be placed lengthwise, with the germ pores pointing obliquely downwards, about 1 inch below the surface and approximately 3 inches apart. The beds, which are exposed to the sun, should be heavily watered at least twice a day. Covering the beds with gunny bags for a few hours during the middle of the day will aid in retaining the heat and moisture, thereby accelerating germination.

Another method, which has shown even greater improvement in the rate of germination, is to employ slightly raised sand beds covered with glass frames. In this case the arrangement of the beds is similar to that described above, except that they are raised about 6 inches by means of rough boards in order to carry the glass frames. The additional heat generated causes the seeds to germinate more rapidly than if planted in ordinary open sand beds.

The seeds should begin to show signs of germination after a period of about 8 weeks. Immediately the cotyledon or seed leaf appears above the surface the seedling should be removed and transferred to a nursery bed. In carrying out this operation great care should be taken to ensure that the seedling is not separated from the seed, since the latter still contains a supply of food in the endosperm.

At this stage the plumule or seed leaf will not be more than 1 inch in length, but the radicle or young root may be

as long as 4 to 6 inches in its endeavour to obtain a supplementary supply of food, consequently the root is liable to be damaged during removal if left longer in the seed bed.

The chief advantage in the use of seed beds, as opposed to planting direct in nursery beds, is the considerable acceleration in the rate of germination. This method has also the additional advantage that seeds, which germinate about the same time, are planted side by side in the same nursery bed resulting in greater uniformity of the plants than if the seeds had been planted direct in such beds.

Preparation of Nursery Beds.—The area selected for the nursery site should be preferably on flat land in the vicinity of a good water supply. If the land is low-lying it is advisable to have the beds slightly raised in order to prevent the plants from becoming water-logged before they are established. The beds are composed of ordinary soil, which should be well dug so that it is in a loose and friable condition preparatory to planting.

As stated above, immediately the seed leaf appears above the surface the seedling should be lifted and transplanted to the nursery bed, great care being taken not to injure the delicate tap root. In transplanting, a hole about 6 inches deep is made with a small sharp-pointed stick, and the seedling placed in the hole with the adhering seed just below the surface. If the rootlet does not reach the bottom of the hole a little fine loose earth should be dropped in to the correct distance. In no circumstances should the tap root be bent if the hole is not of sufficient depth. The soil is then tamped well round the root to ensure the plant being firm, since any seedling which is so loose in the ground as to be easily lifted will have considerable difficulty in becoming established.

If the weather is dry at the time of transplanting, the young seedlings should be carefully watered for several days until they appear to be established. The seedlings are fairly hardy and do not require any shade, even at this stage.

The distance of planting depends on the period during which the plants are to remain in the nursery beds, and this period is dependent on the age when they are to be transferred to the field, (see Plate III, figs. 1 and 2). If the seedlings are required to be planted in the field within 9 months,

they may be planted in the nursery beds at a distance of about 1 to 1½ feet apart but, if they are to remain there for a longer period, they should not be placed closer than 2 feet apart.

PLANTING IN THE FIELD.

After felling and burning operations are completed and the necessary drains have been dug, the land is partially cleared of timber, lined and holed for planting. In order to obtain the best results planting should be carried out preferably during one of the recognised wet seasons, October to December or March to April.

Transplanting.—The planting distance having been decided upon, holes not less than 2 feet square and 2 feet deep should be dug in the field in preparation for transplanting the plants from the nursery beds. If the soil is poor it is advisable to increase the size of the holes, otherwise the plants may be stunted and uneven in growth. The holes, which are usually left exposed to the air for a few days, are filled with good surface soil immediately before planting. Wood-ashes, available as a result of the burn, should be mixed with the soil placed in the holes.

When the plants are lifted from the nursery beds, it is most important that they should have a good ball of earth round the roots so as to give the plants as little check as possible on transfer to the field. Any roots injured during this operation should be removed with a sharp knife.

The hole having been filled with good soil to the required depth, the plant is placed in a slight depression with its collar flush with the surface. The soil should be well pressed round the roots, so that the plant is firmly fixed in the ground. The first rains will soon wash in sufficient soil to fill up the small depression. Planting either too deep or on mounds raised above the ground should be avoided.

The plants may be transplanted in the field with as much success when 6 months old as when they are 18 months old, if this operation is carried out carefully. It will be found that plants about 9 months old can be more readily handled both in the nursery and in the field, and this is probably the best age for transplanting. On the other hand the danger of rats damaging young palms is much greater than with palms more than one year old.

The oil palm stands transplanting fairly well under ordinary conditions and very little supplying is necessary.

Distance of Planting.—The correct distance of planting depends upon the type of soil, sufficient space being allowed for the proper development of the palms from the outset. In this connection it is significant to note that palms can be planted closer together on poor soil than on rich soil, so that it is impossible to lay down any definite rule as to the correct distance. Too close planting cannot be too strongly condemned, whilst too wide planting may prove unprofitable. It is obvious, therefore, that the distance to be allowed between the palms needs careful consideration, since any defect in spacing cannot be rectified later.

The development of the crown may be taken as a basis for spacing, and the most suitable arrangement is to obtain the maximum number of palms to the acre without interfering unduly with their development.

The triangular or equilateral system of planting is recommended in preference to the square or rectangular system, since the former gives a better arrangement of the palms and also a greater density per unit area with ample space for the development of the crowns.

This point is illustrated diagrammatically in Plate IV, which shows square planting 30 feet apart compared with triangular planting of the same distance. From this diagram it will be seen that with square planting there are approximately 48 palms per acre, whilst with the triangular system there are approximately 55 palms per acre.

The distance between the palms and also the number of palms per acre are usually decided by the length of the leaves of mature palms already established in the district.

Measurements of leaves on various plots at the Government Experimental Plantations at Kuala Lumpur and Serdang, where the palms are growing under different soil conditions, have shown considerable variation. On poor soil the average spread of the leaf (horizontal distance between base and tip of leaf) is only 12 feet, while on fairly good soil the spread is about 14 feet. On a few isolated palms, growing in rich soil, a leaf spread of over 20 feet has been recorded, but this is exceptional.

The conclusion drawn from these and other observations is that under good conditions the most suitable planting distances are 30 ft. x 30 ft. square (48 palms per acre) or 30 ft. x 30 ft. triangular (55 palms per acre), the latter system being preferable. If the soil conditions are poor, the planting distance may be reduced to 28 ft. x 28 ft. triangular (64 palms per acre), but in no case should the palms be planted closer than 26 ft. x 26 ft. triangular (74 palms per acre).

PLANTING SYSTEMS

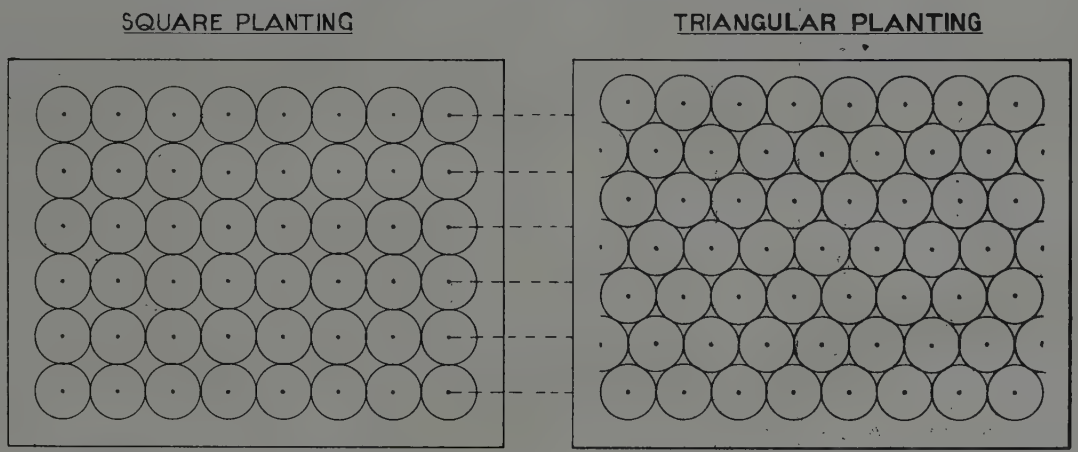


PLATE IV.

V.--Upkeep of Plantation.

Cultural operations, such as weeding, planting of cover crops and green manures, prevention of soil wash, cultivation, manuring and pruning of leaves, are described briefly under this heading. In addition, it is considered advisable to refer also to the possibility of growing catch-crops with oil palms.

WEEDING.

The harmful effect of weeds on the growth of any cultivated crop is so well known as to render further comment unnecessary and, assuming that cover crops are not to be established, it will be realised that particular attention must be given to this operation.

The most satisfactory method of weeding is undoubtedly the clean weeding system, whereby only the principal crop is allowed to occupy the ground. Such a system, however, is only practicable on flat land, which is not liable to soil wash.

Under this system the land is kept clean by carrying out regular weedings at intervals of about 2 to 3 weeks, the weeds being left on the surface of the ground to dry in the sun. The intervals between weedings should be so arranged as to preclude the possibility of the production of seed from any weeds, which might have become re-established since the last weeding operation.

Another less expensive, but less effective, method is known as selective weeding. In this case only the more harmful weeds are removed, except for a small area which is kept clean around each palm. Under this system closer supervision is necessary than with clean weeding since there is always the danger of allowing noxious grasses, such as lalang (*Imperata arundinacea*), to become established.

The retention of harmless weeds may assist in preventing the loss of surface soil on hilly land, but it is less effective than growing cover crops on such land.

COVER CROPS AND GREEN MANURES.

The cultivation of cover crops during the initial stages of development of the palm has generally a beneficial effect

on its growth, and at the same time assists in reducing expenditure on upkeep by suppressing the growth of weeds. In addition, cover crops improve the soil conditions by minimising the baking action of the sun on the soil, while those of a low-growing habit assist materially in the prevention of surface wash on steep land. Their cultivation on light soils is particularly beneficial, since they add humus to the soil, especially if the cover plants are ploughed in at intervals. It is doubtful, however, whether their growth assists in checking the loss of soil moisture due to evaporation.

If cover crops are to be successful, it is important that they should be established immediately after the palms are planted, while the land is free from weeds. Further, particular attention must also be given to weeding until the cover crop is well established, otherwise the latter may ultimately prove a failure.

For general purposes low-growing leguminous cover plants, such as *Calopogonium mucunoides*, *Centrosema pubescens*, *Indigofera endecaphylla*, *Pueraria phaseoloides*, *Dolichos Hosei* (*Vigna Hosei*), and the "composite" *Mikania scandens*, are probably the most suitable. Whether the cover plants are established from seed or cuttings, they are best planted in rows about 3 feet apart and the same distance apart in the rows, (see Plates V and VI).

As the palms increase in age and the ground becomes shaded, a permanent type of cover plant, such as *Dolichos Hosei* (*Vigna Hosei*), which will thrive under such conditions, should be selected in preference to say *Calopogonium mucunoides*, which is comparatively short-lived and will not thrive under shade.

It will be realised that, owing to varying conditions and differences in types of soil, it is impossible to make any definite recommendation as to the most suitable cover plant for general adoption. This question can only be decided by establishing small experimental areas of the more suitable types of cover plants on the estate.

Further, the possibility of establishing a combination of cover plants on the same area should be given consideration in view of the different habits of growth and the variation in the duration of these plants under rapidly changing con-

Two-year Old Palms with_Calopogonium_Mucunoides as a Cover Crop.

PLATE V

Two-year Old Palms with Centrosema Pubescens as a Cover Crop.

PLATE VI

ditions, for example, good results have been obtained on some estates with a mixture of *Centrosema pubescens* and *Dolichos Hosei* (*Vigna Hosei*).

With regard to green manuring, in which the main object is to enrich the soil in humus, the cultivation of the erect type of leguminous cover plants, such as *Tephrosia candida* and *Crotolaria anagyroides*, is recommended. These are planted in rows at distances of about 4 feet apart and 2 feet apart in the rows. When the plants are about 6 months old, the young shoots should be pruned back and the prunings dug into the soil. The plants are then allowed to grow again and pruning operations are repeated at intervals of about 4 months. By this means a large quantity of organic matter is returned to the soil, thus improving its fertility.

Crotalaria anagyroides is not a perennial plant and under ordinary conditions will only last about 1½ to 2 years without replanting, but *Tephrosia candida* will continue to grow for at least 3 to 4 years, even when periodically cut back.

Apart from its value as a green manure, *Crotalaria anagyroides* is a particularly strong growing plant and its deep-rooting habit has been found of value in breaking up the lower layers of impervious soils.

PREVENTION OF SOIL WASH.

In addition to the cultivation of the low-growing or creeping type of cover plants mentioned above, there are other methods which can be adopted for the conservation of the soil on either undulating or hilly land liable to surface wash.

A satisfactory, but somewhat expensive, method is the construction of terraces on the contours. These terraces are spaced at suitable distances apart, and the palms are planted midway on the levelled surface so as to allow of the terrace being widened later if considered necessary.

Another method, which has given satisfactory results, consists in digging contour drains and placing the excavated soil above the drains with the object of forming a terrace.

In some cases, one or other of the erect type of cover plants, such as *Tephrosia candida*, or one of the strong

growing grasses, such as citronella grass, can be planted on the edges of the terraces in order to break the flow of water and thus prevent erosion.

Silt-pits or catchment drains are also constructed to assist in the conservation of the soil on steep land. These are usually about 20 feet long, 2 feet wide and 2 feet deep and, contrary to ordinary practice, are placed above the individual palms, the lower edge of the pit being about 6 feet away from the palm. By this means the rain water collects in the pits and gradually filters through the soil to the roots of the palm, thus giving the latter an additional supply of moisture. This method has been employed successfully at the Experimental Plantation, Serdang.

It is considered, however, that the planting of low-growing cover crops is probably the cheapest and most suitable method to adopt for the prevention of soil wash, provided that no time is lost in establishing the cover crop after the land has been opened up

If, owing to lack of funds, it is found impossible to establish a cover crop, or to carry out any of the other methods described above, the system of selective weeding may be adopted as a last resort. In no case, however, should the clean-weeding system be adopted on hilly land, otherwise permanent damage will be caused by the loss of the valuable surface soil, which contains most of the available plant foods. Once the surface soil is lost the value of the plantation will be seriously diminished, since the palms can no longer obtain the necessary plant nutrients to sustain normal yields.

CULTIVATION.

The principal objects of cultivation are the elimination of weeds, the conservation and improved distribution of soil moisture and the proper aeration of the soil, all of which encourage the activity of useful soil bacteria. Further, plants are unable to derive full benefit from manuring when the land is not maintained in a good state of tilth.

On most plantations cultivation usually consists in systematic weeding, with an occasional changkolling or forking to a distance of 4 to 5 feet from the base of the palms. In certain instances, however, regular ploughing or

Ten-year Old Palms on an Estate in Malaya.

PLATE VII

disc harrowing is practised with beneficial results. These cultural operations, when properly carried out, improve both the chemical and physical condition of the soil. The distribution of water in the soil is more evenly regulated, rain falling on the cultivated surface is more rapidly absorbed, while the loose surface, produced by cultivation, acts as a mulch and prevents the rapid evaporation of moisture. Cultivation also acts indirectly, principally through the soil bacteria, in making the existing plant foods more readily available. Plate VII illustrates the method of cultivation at present employed on most estates in this country.

On a large scale, cultivation can only be carried out economically by the use of ploughs and disc harrows, drawn by either bullocks or tractors. If a creeping type of cover crop is planted it is difficult to carry out such operations, since the straggling mass of green material causes mechanical trouble. In estate practice, therefore, cultivation by mechanical means is considered an alternative to the planting of cover crops and more suitable for flat land usually kept in a clean weeded condition.

Bullocks or buffaloes are probably the cheapest and most efficient form of draught. With a type of plough specially designed for these animals it is possible in the lighter type of soils to plough to a depth of about 6 inches, one man and a good pair of bullocks being able to plough from one-half to three-quarters of an acre per day.

A light type of cultivator, which has also been designed for this purpose, consists of six curved tines, three in the front alternating with three at the back. On land which has been ploughed previously a man and a pair of bullocks with this implement will cultivate about 3 acres per day.

The chief disadvantage in the use of tractors is the serious loss of time due to frequent mechanical breakdowns, which demand therefore the employment of drivers with a specialised mechanical training capable of dealing with these defects. A further disadvantage of tractors is the difficulty of obtaining supplies of spare parts, but this can be overcome to a large extent by the more general adoption of one type of tractor.

Providing no mechanical trouble is experienced, a tractor with a driver and attendant will plough from 3 to 4

acres per day, while with a disc cultivator it is possible to cover an area of from 10 to 15 acres a day.

MANURING.

The question of the manuring of oil palms has not yet received much attention, but the matter will undoubtedly have to be considered when the palms become older, if satisfactory yields are to be maintained.

In order to obtain some indications as a guide to manuring, it is necessary to determine approximately the amounts of the different plant nutrients removed from the soil when the palms are in bearing. With this object in view the Department is undertaking the chemical analyses of the leaves, flowers and fruits of palms growing under different soil conditions. This investigation has not progressed sufficiently to warrant the publication of any results at this stage.

When this information is available it will be possible to draw up a definite scheme of manurial experiments with a view to the improvement of yields on different types of soil. The profitable use of artificial fertilisers from a practical standpoint can only be determined by carrying out numerous experiments on palms in bearing and, in view of the relatively large quantity of material removed annually from the palms in pruning the leaves and harvesting the fruit bunches, the application of artificial manures will certainly have to be considered later.

In the meantime the fertility of the soil may be maintained to a certain extent by the use of green manures and also by returning to the soil the leaves, fruit stalks and ashes of the fruit refuse from the factory.

PRUNING.

When the palms reach the producing stage the pruning of the lower leaves should be commenced, but it is important to carry out this operation judiciously, since considerable damage may be caused if too many leaves are removed within a given period.

Pruning experiments have been carried out at the Experimental Plantation, Serdang to show the effect of (*a*) light, (*b*) medium and (*c*) heavy pruning on four-year old palms by

Four-year Old Palm Lightly Pruned.

PLATE VIII

Fruiting Palm Showing Normal Method of Pruning.

the removal of one, two and three leaves per month respectively. These experiments proved that the last method was too drastic, since it resulted in an abnormal increase in the height of the palm with a corresponding reduction in the girth of the trunk. This indicated clearly that the palms were becoming exhausted in their endeavour to produce new leaves. The condition of the palms was similar to that usually produced by starvation on poor soil or by lack of cultivation after having been well established.

Further, similar experiments conducted in Sumatra (11) on palms in full bearing showed that while heavy pruning gave a temporary increase in the yield of fruit bunches it resulted eventually in a serious decrease in the production of fruit, thus clearly demonstrating the ill-effects of excessive pruning.

Until the palm is 3 to 4 years old, pruning should be restricted to the removal of those leaves which have dried up and have therefore ceased to function. If this practice is adopted the young palms will produce good sized trunks, thus firmly anchoring themselves, which is a considerable advantage when palms are planted in the looser types of soil, (see Plate VIII).

The production of leaves on a four-year old palm is normally about 20 per annum, the number increasing gradually to about 24 per annum in the tenth year. After the fifteenth year this number decreases slowly to an average production of about 16 leaves per annum.

It has been shown above that the minimum amount of pruning gives the best results, consequently no further pruning should be done than is necessary to harvest the fruit bunches. In pruning operations the leaves should be cut close to the trunk, the cut being made with a sharp axe in a sloping direction, (see Plate IX).

The fruit bunches are borne in the axils of the lower leaves, but, since during the year only 8 to 10 leaves carry fruit bunches, less than half the number of leaves produced annually will be removed in harvesting these bunches. A systematic pruning should therefore be carried out at least once a year, in order to remove any leaves below those carrying the fruit bunches in process of development. Since this extra pruning cannot be done during harvesting operations,

a special pruning gang is usually employed to undertake such work.

In any case, the number of leaves removed annually should be restricted to the number produced during this period under normal conditions. When an excessive number of leaves is removed there is not only a diminution in the yield of fruit, but the palm tends to produce new leaves more rapidly and to increase in height at the expense of girth.

In practice, the leaf carrying a fruit bunch in its axil should always be left to support the bunch, since any pressure caused by the leaves does not appear to restrict the development of the bunches.

The new leaves are formed immediately above the old ones, and it is interesting to note that very early in the development of a palm the older or lower leaves attain their maximum spread.

The dimensions and weights of leaves from different palms show considerable variation. Assuming the average weight of a freshly cut leaf to be 12 lbs. and allowing for the removal of 20 leaves from a palm each year, with a stand of 55 palms per acre the amount of fresh material removed by pruning is approximately 13,000 lbs. per annum, equivalent to the removal of 4,500 lbs. of dry matter per acre per annum. It will be realised, therefore, that relatively large amounts of plant nutrients may be removed by pruning and, if these nutrients are to be conserved, it will be necessary to adopt some regular system for the disposal of the leaves, (see Plate X). Further information on this point will be available when the chemical analyses of the leaves have been completed.

CATCH-CROPS.

Catch-crops may be a valuable source of revenue during the development of the principal crop, but it must be admitted that the plant food removed from the soil by them is bound to retard to a certain extent the growth of the main crop. Compared with either rubber or coconuts, the oil palm develops rapidly, and for this reason only catch-crops of a comparatively short duration, such as tapioca, can be considered. Experiments with tapioca as a catch-crop are at present being carried out at the Experimental Plantation, Serdang (10).

Method of Disposal of Pruned Leaves.

PLATE X

One-year Old Palms with Gambier Planted as a Catch-crop.

In some cases, where wide planting has been adopted, robusta coffee has been cultivated successfully as a catch-crop, but it was established in the early stages before the palms had shown much development. In the case of long duration catch-crops, such as robusta coffee, gambier, bananas and pineapples, it is a considerable advantage to plant the catch-crops at least one year before the oil palm.

Although catch-crops may reduce weeding costs by increasing the shade, they are a disturbing factor as regards the allotment of labour and supervision on the plantation, particularly when the catch-crop has to be harvested. This must result in occasional neglect of the main crop in districts where a supply of casual labour is not available.

Allowing for the fact that the oil palm develops rapidly and under ordinary conditions reaches its maximum spread of foliage at about 3 to 4 years after planting, thereby heavily shading the ground, the cultivation of catch-crops, except those of comparatively short duration, is therefore not recommended, since there is usually insufficient time in which to obtain full benefit from their cultivation. As stated above, this disadvantage can be overcome in the case of catch-crops of long duration, such as robusta coffee, gambier, bananas and pineapples by planting them at least one year ahead of the main crop, (see Plates XI and XII).

VI.—Artificial Pollination.

It is now recognised that during the early stages of production attention must be given to the question of artificial pollination in order to obtain satisfactory yields of fruit. There is little doubt that, if the palms are left to nature when they commence to flower, a large proportion of the female inflorescences will fail to be properly pollinated by natural means. Under such conditions only a comparatively small number of fruits develops on each bunch, thereby resulting in a serious diminution in the average yield of fruit per palm.

In view of the importance, therefore, of artificial pollination it is considered necessary to give a botanical description of both male and female flowers, in order that this operation may be understood.

The flowers of the palm are unisexual, which means that they consist either of pistils (female flowers) or stamens (male flowers), produced separately, but on the same palm. Typical male and female flowers are shown on Plate XIII, figs. 1 and 2.

Freak palms occur occasionally, which produce only either male or female flowers, the latter being invariably sterile. Such palms, which are abnormal, are usually characterised by their increased size compared with normal palms of the same age.

The inflorescence is compound, that is to say, it is composed of branches consisting of secondary inflorescences. The side branches, which bear the flowers, are arranged spirally on a short main axis which projects to form spines, these being particularly well developed in the female inflorescence.

As will be seen from Plate XIII, the individual female flowers are somewhat widely separated, while the male flowers are closely packed together in the form of club-shaped branches, usually called fingers.

An examination of inflorescences from palms of different ages shows that the number of the individual flowers in both cases increases considerably with the age of the palm.

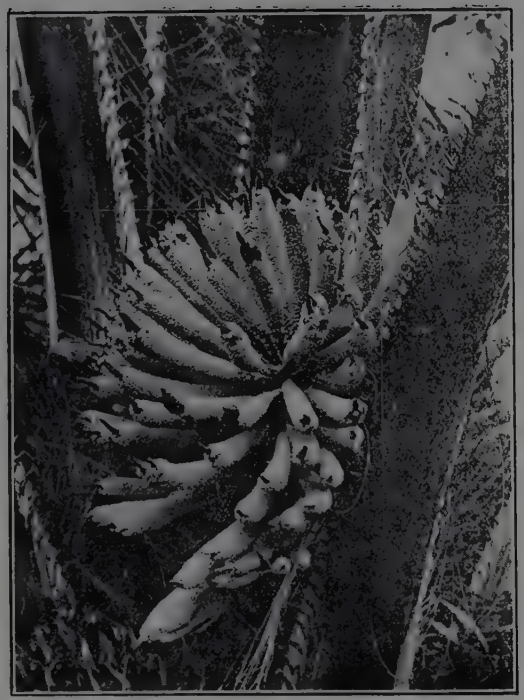


Fig. 1.—Male Inflorescence.

Fig. 2.—Female Inflorescence.

PLATE XIII

For example, in the case of five-year old palms the average number of flowers on a female inflorescence was approximately 3,500, while on an inflorescence from a ten-year old palm the number of flowers was approximately 5,000.

Similar counts for male inflorescences gave approximately 50,000 individual flowers for an inflorescence from a five-year old palm, increasing to approximately 140,000 individual flowers for an inflorescence from a ten-year old palm.

At first both the male and female inflorescences are enclosed in double fibrous sheaths. The outer sheath bursts open soon after the inflorescences begin to develop, but the inner sheath does not split until about two weeks before the flowers begin to open. The increase in the length of the stalk of the male inflorescence forces the latter through the top of the sheath, but the stalk of the female inflorescence is so short that parts of it still remain covered by the fibrous sheath whilst flowering, thus preventing proper pollination.

The distribution of sex in an individual palm shows great variation, and it is possible to find palms with a preponderance of either male or female inflorescences or an equal number of both in different stages of development. As a rule, however, the palms have definite cycles in which either male or female inflorescences are produced. A "female" cycle, during which only female flowers are produced and which usually lasts for a period of three months, sometimes six months, is followed by a resting period of three months, and then a "male" cycle of about the same length as the "female" cycle. These cycles are not seasonal, and both male and female cycles may occur at the same time on different palms. Instances have been recorded in which both mature male and female flowers appeared together on the same palm, but such occurrences are comparatively rare.

When the male flowers are ripe, the anthers split along the inner edges and the pollen is discharged. Provided that the pollen grains are stored in a desiccator containing lime, they retain their germinative power for a period of about six weeks. On the other hand, large quantities of pollen grains lose their vitality in a very short time, unless special measures of preservation are taken. According to Heusser (12), pollen stored in an airtight bottle will be dead within 48 hours, but pollen collected in the early afternoon, when quite dry and spread out on paper or placed in an open receptacle, will remain virile for several days after collection.

Both male and female flowers possess a strong smell of aniseed when they reach full development.

The female flower usually has three ovules, but as a rule only one is fertilised, occasionally two, and very rarely three. The female flowers remain receptive for a period of only three days and the most suitable time for pollination is between the second and third day, when the inner white surfaces of the pistils have turned completely red. On the fourth day a violet colour develops, at which stage the flower begins to wither.

When carrying out artificial pollination the area to be pollinated should be patrolled at intervals of at least three days, otherwise a proportion of the female inflorescences will not be fertilised.

In collecting the pollen the male inflorescence is carefully removed from the palm and held over a large metal funnel into which it is shaken, the loose pollen grains falling through into a receptacle placed below.

As stated above, the pollen should be collected early in the afternoon when the atmosphere is dry and stored either on sheets of paper or in glass stoppered bottles containing unslaked lime. It is important that such pollen should be collected from fresh inflorescences which still retain a strong odour of aniseed.

The operation of artificial pollination is simple and consists in dusting lightly a small quantity of the fresh pollen over a bunch of receptive female flowers.

Although the process is simple, it is necessary in practice to train coolies for this work. Each pollinator is given a supply of fresh pollen in a small perforated tin and, after satisfying himself that the inflorescence is ready for pollination, he frees it from any extraneous matter and then carefully sprinkles a small quantity of pollen over the open flowers. Pollination can be carried out successfully at any time during the day.

A trained cooly can pollinate about 20 acres per day, so that he is placed permanently in charge of an area of about 60 acres, which is considered the maximum area which one cooly can conveniently patrol. Under this system the

Fruit Bunches on an Artificially Pollinated Five-year Old Palm.

PLATE XIV

pollinator will cover one-third of the area each day, thus returning to the beginning of the block at intervals of three days. It is stated that after a time a pollinator becomes so well acquainted with the palms in the block under his control that he knows at a glance which palms are likely to be ready for pollination on his return visit of inspection.

Since the pollen is principally wind borne, the question of practising artificial pollination as a means of increasing the yield of fruit on plantations must therefore be given consideration during the first 5 or 6 years of production.

The effect of a regular system of artificial pollination is illustrated in Plate XIV.

The inflorescences at this stage are produced comparatively close to the ground, but it is now generally recognised that with an increase in the height of the palm pollination may be left to natural agencies without affecting the production of fruit.

Experiments in artificial pollination, conducted at the Experimental Plantation, Kuala Lumpur, with palms growing on comparatively poor land, proved that this operation can be carried out to excess. In this particular case over-pollination by artificial methods resulted in a reduction both of the size of the fruit and of the percentage of pericarp. In order to confirm these results, experiments on a much larger scale are now in progress at the Experimental Plantation, Serdang.

VII.—Diseases and Pests.

DISEASES.

There is at present little detailed evidence relating to the diseases of oil palms, but from various observations made by this Department there are definite indications that the subject will have to be considered carefully when large areas are planted with this particular crop.

Among the diseases which have been observed on the various oil palm estates in Malaya may be mentioned the following:—

(*a*) Bud-rot of mature palms.

(*b*) Crown disease of young palms.

(*c*) Marasmius disease of fruit bunches.

(*d*) Miscellaneous affections of fruit bunches.

Brief descriptions of the symptoms of each disease, together with suitable measures for treatment, are given below.

(a) *Bud-rot of Mature Palms.*

As a result of work carried out during the last few years the position with regard to this classical disease, known as "Bud-rot of Palms", has been cleared up considerably and it is now recognised that in the past many different affections have been classed under this heading.

"Bud-rot" of mature oil palms has been a prominent feature in Malaya and caused trouble for some years on one estate, several groups of 6—12 mature palms being lost annually. The most prominent feature of the diseased palms was a distinct, vile-smelling rot of the tender bud tissues.

Precautionary measures were adopted and, as only scanty information was available, the estate was advised to cut out and destroy the diseased palms as quickly as possible. Though these instructions were carried out carefully for two or three years the situation did not improve.

Later work showed the possibility of preventive treatment by cleaning out the diseased bud tissue, and by placing in the cavity a quantity of common salt or copper sulphate. As an added precaution, and for ease of

Fig. 1.—Palm Recovering from Bud-Rot.

Fig. 2.—Palm Affected with Crown Disease.

treatment, the first group of treated palms was cut out and placed between palms in other rows. The treated palms took root again quickly and recovery was rapid and complete, (see Plate XV, fig. 1). Later, further modifications were considered, until finally the position has been reached that no treatment is given to palms showing signs of this particular type of "bud-rot". Over a period of several years only one "bud-rot" palm has been lost, the disease travelling down into the stem and completely rotting it. A sharp watch is being kept for cases which seem abnormal, but at the present time in Malaya the position is that "bud-rot" of mature oil palms cannot be considered a serious disease.

(b) *Crown Disease of Young Palms.*

The so-called "Crown" disease affects palms usually under two years of age, although the affection has also been observed on palms five or six months after planting in the field.

The symptoms are characteristic. One of the central leaves, usually the third or fourth from the most recently opened leaf, begins to bend over from its almost upright position. If this leaf is examined, a water-logged area, three to four inches in length and more transparent than the remainder of the leaf, is found at the base.

As the young palms make rapid growth and the affected leaf is pushed out, the drooping becomes more pronounced. All the leaves situated externally to the first affected leaf become similarly affected and the palms at this stage show a series of pronounced drooping leaves surrounding the few remaining central leaves, which still stand stiff and upright, (see Plate XV, fig. 2). The drooping leaves present a peculiar appearance, being bent at the middle and possessing no leaflets about the region of curvature. The upright central leaves remain unaffected and continue to grow in a normal manner. Ultimately a new crown of healthy leaves is produced surrounded below by the affected drooping leaves.

So far no casualties have been reported, the total extent of the damage being that the growth of affected palms has been retarded for some twelve months. A high percentage of infection is sometimes found, and in such cases the trouble appears to be serious, but it is significant that the palms finally recover.

This disease has been described as a form of "Incipient Bud-rot". While the explanation for the appearance of the affected leaves seems obvious, the cause is somewhat obscure, the presence of neither fungi nor bacteria having been demonstrated in recently affected tissues.

It has been suggested that excess of nitrogenous food material in the soil may be the chief contributory cause, but as the affection appears on all types of soil in Malaya where oil palms are planted, even on soils which might be considered deficient in this particular plant nutrient, the explanation seems doubtful. Much work will be necessary before the reasons for the peculiar conditions observed are elucidated.

(c) *Marasmius Disease of Fruit Bunches.*

Only a single case of this particular disease has been noted in Malaya, but the conditions were so peculiar that special consideration is necessary.

If the inside surfaces of the bases of the older leaves are examined, white fungus strands can usually be found. Owing to the close union of stem and leaf, moisture is firmly retained and conditions for growth of various types of saprophytic fungi are very favourable. The commonest fungus forms white strands and often is developed so profusely as to form a "mat" on the inside of the leaf base.

The non-pollinated or partially pollinated bunches, showing only a few under-sized fruits, also form a favourable place for the growth of this fungus. In this particular case the fungus formed a small mushroom-shaped fruiting body, the head being pinkish-white in colour and carried on a white stalk. In nature the head is about $\frac{1}{2}$ in. in diameter and the stalk $\frac{1}{2}$ to 1 in. in length. The fungus belongs to the genus *Marasmius*.

So long as the fungus confines its activities to the non-pollinated bunches and to the leaf-bases, where it does not penetrate the tissues, there is no cause for alarm. On one palm, however, the fungus attacked eight practically mature, well-developed fruit bunches and rendered them useless for oil production.

The feature of apparently saprophytic fungi becoming educated to function as parasites is well known in plant

pathology, and for this reason a serious view of this particular case was taken. The most reasonable suggestion to account for the appearance of these symptoms was that the fruits in the partially-pollinated bunches proved more or less suitable as a growing medium for some strain of this particular fungus and that, starting from this position, a fungus strain might have been developed which would prove to be habitually parasitic. Thus, the cutting out of these fruit bunches appeared advisable and since this has been done no more cases have been found.

On another estate, observations made on five-year old palms in bearing showed that the non-pollinated bunches were in most cases centres for the growth of another *Agaric* fungus. This fungus was not observed to attack the mature fruits of pollinated bunches, but in those bunches in which about 50 per cent. of the fruits had matured the remaining undeveloped fruits were covered with a growth of the *Agaric* fungus, which appeared to be responsible for their disintegration.

The male inflorescence, which only persists for a few days, frequently becomes covered with fungi, chiefly *Fusarium* spp., and disintegrates. The *Agaric* fungus mentioned above is not often seen growing on the male inflorescence.

(d) *Miscellaneous Affections of Fruit Bunches.*

Two other affections of fruit bunches have also come under observation.

The first appears as a premature ripening and hardening of the individual fruits. The latter, when ripe, drop from an unaffected bunch quite easily, but in affected bunches it is very difficult to separate the fruits and, even when separated, they are found to be of little value for oil production. The cause is not known and it is difficult even to suggest any contributory factors.

The second affection is the opposite of the above, the pericarp of the individual fruits becoming soft and slimy, suggesting a bacterial cause.

Both these affections call for investigation as soon as possible.

B. INSECT PESTS.

The oil palm in Malaya is at present singularly free from injurious insects and none has yet proved of economic importance. In the main, those well known on the coconut palm are the most likely to prove troublesome to oil palms in the future; although so far the Zygaenid moth, *Artona catoxantha* Hamps. and the Hispid beetle, *Plesispa reichei* Chap., (the two-coloured leaf beetle), both pests of the coconut, have not even been recorded on the oil palm. In general, the oil palm has proved to be far less liable to the attacks of insects than the coconut palm.

(a) *Insects Recorded as Causing Damage.*

Rhynchophorus schach Oliv. (The red-stripe weevil).

This is the most dangerous insect so far recorded on the oil palm in Malaya since, once having gained an entry, it invariably kills the palm. This insect can, however, be successfully controlled by the methods described below.

The weevil varies in size, averaging about 45 mm. in length, including the snout, and about 17 mm. in breadth. It is black in colour with an orange-red stripe down the middle of the thorax. The eggs, which are laid on freshly wounded surfaces, especially the cut ends of pruned leaf-stalks, hatch in about three days. The grubs are legless, wrinkled, white in colour with a dark chestnut-brown head and, when full-grown, about 55 mm. in length. Emerging from the eggs, the grubs bore into the palm, tunnelling the stem in every direction and so causing the ultimate death of the palm. The larval or grub stage can be completed in fifty nine days. When the grub is full-grown, it constructs inside the palm a cocoon, elliptical in shape, about 70 mm. in length and composed of twisted fibres. Inside this, it changes into a pupa from which the weevil emerges in about twenty five days, (see Plate XVII).

Control measures for this insect consist in (*1*) preventing injury to the palm such as may be caused by (*a*) careless pruning and (*b*) by the attacks of the black or rhinoceros beetle, (*2*) carefully dressing all wounded surfaces and (*3*) practising estate sanitation.

With regard to careless pruning it may be mentioned that the grubs of this insect have been observed to tunnel

Explanation of Plate XVI.

Fig. 1. *Amathusia phidippus.*
(a) caterpillar,
(b) pupa.

Fig. 2. *Setora nitens.*
(a) caterpillar,
(b) pupa.

Fig. 3. *Creatonotus transiens.*
(a) caterpillar
(b) pupa.

Fig. 4. *Mahasena* sp.
(a) caterpillar,
(b) pupa.

Fig. 5. *Hidari thrax.*
(a) caterpillar,
(b) pupa.

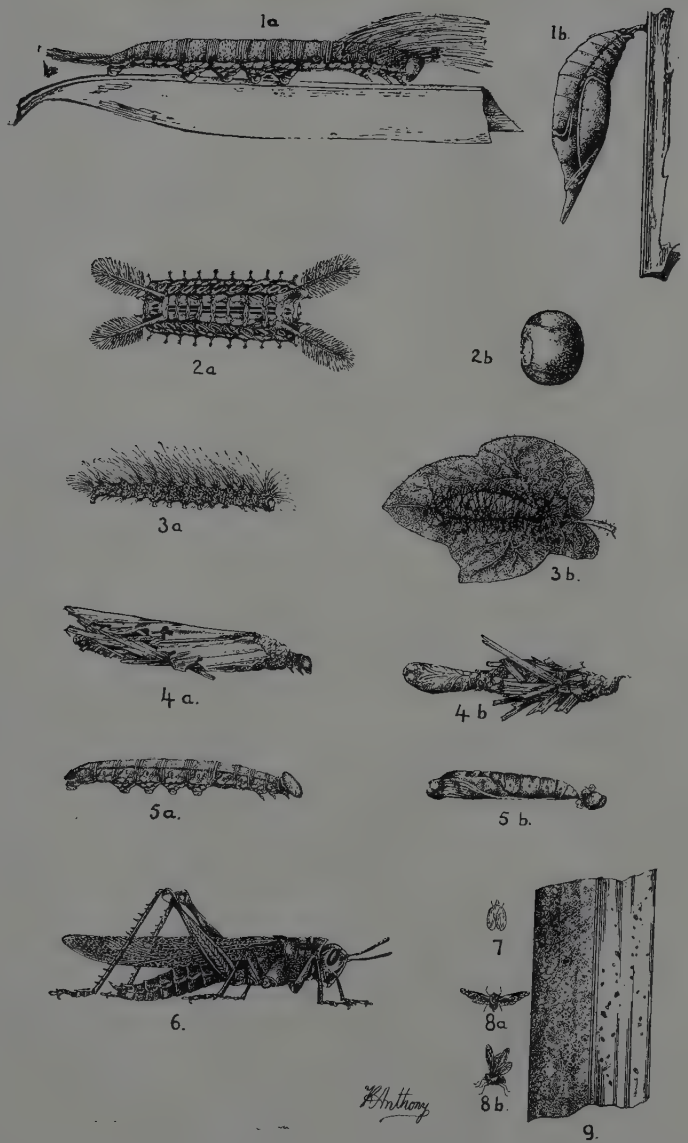
Fig. 6. *Valanga nigricornis.*

Fig. 7. *Tambinia capitata.*

Fig. 8. *Phenice moesta.*

Fig. 9. *Cerataphis lataniae* on leaf of oil palm.

NOTE.—The drawings are slightly less than natural size.



Insect Pests of Oil Palm.

through 36 inches of coconut and 15 inches of oil palm leaf-stalk and so to enter the trunk. It is particularly important to tar, at least twice, the pruned ends of leaf-stalks and the surfaces of any accidental wounds, to prevent the weevils from laying eggs. This weevil will not attack sound palms, but may take advantage of any holes bored by the black beetle through the leaf-stalks. Consequently, the destruction of breeding grounds suitable to the black beetle also forms a necessary part of the control of the red-stripe weevil. This weevil can breed in recently felled palms of several species, so that all such should be burnt within two months of felling, in order to destroy all the stages of this weevil which may be present in the wood.

Oryctes rhinoceros L. (The black or rhinoceros beetle).

Instances of this insect attacking the bases of the leaf-stalks and also gnawing the young unopened leaves above the bud have been observed. Up to the present, such injury has not proved fatal to the oil palm and, moreover, the red-stripe weevil has not been seen to take advantage of these wounds on the oil palm, although it commonly does so on the coconut.

The adult beetle is a large black insect, about 40 mm. in length and 20 mm. in breadth, with a projecting horn on the front of the head. The beetle, not the grub, attacks palms. It lays its eggs in decaying trunks and stumps of palms and heaps of decaying vegetable matter of all kinds, such as village refuse, sawdust and manure. The egg, which is oval in shape, white in colour and about 3 mm. long, hatches in ten to eighteen days. The grub is bluish-white in colour with a brown head and three pairs of brown legs on the thorax. The body of the grub is curved and the terminal end is much swollen and deeper blue in colour. The grubs feed in the refuse and when full-grown are about 7 cm. long. After about 3 months they construct, in the refuse or in the soil below, oval cocoons, inside which they pupate and from which the beetles emerge in about one month, (see Plate XVII).

The control of this insect is intimately associated with the destruction of all decaying vegetable matter. This beetle has not been found in the refuse heaps on oil palm estates, but these accumulations, which are likely to prove suitable for breeding, should be regularly inspected and, if necessary,

destroyed, to prevent the occurrence of an outbreak of this insect.

Coptotermes gestroi Wasm. ("White ants").

Oil palms are not immune to the attacks of this insect, which is so familiar to those engaged on rubber estates. Clearing the land of all timber is the most efficient control and, until this has been done, *Coptotermes gestroi* is always liable to cause injury.

Mahasena sp. ("Case-worm").

The caterpillars of this Psychid moth have been found occasionally eating the leaves of oil palms. The caterpillar lives in a case composed of pieces of leaves woven together with silk, which it carries about on the palm, its head only emerging from the case. Only the male attains the winged condition; the wingless female lays eggs in its case and gradually shrinks as the eggs fill the lower half of the case. This insect is often confined to a group of a few palms in a field and, where this occurs, collecting and destroying the cases is the only control measure necessary, (see Plate XVI).

This insect, or a similar species, has occasioned considerable damage to coconuts and spraying the palms with lead arsenate (2 lbs. in 50 gallons of water) and banding them with a sticky substance have been found to be necessary. The use of the sticky bands will be understood when it is mentioned that during an outbreak hundreds of caterpillars, beaten to the ground by rain and wind, have been observed attempting to re-ascend the palms.

Valanga nigricornis Burm. (Short-horned grasshopper).

This is a very large grasshopper, being about 70 mm. in length, yellowish-green in colour with black markings and pink underwings. It has been recorded on several occasions damaging the leaves of essentially young palms, more particularly when a cover crop of Giant Mimosa (*Mimosa invisa*) is growing. This grasshopper occasionally increases to large numbers and seems to be particularly attracted to Giant Mimosa. Where this has occurred, the removal of the cover crop has caused the disappearance of the insect and the eventual recovery of attacked palms, (see Plate XVI).

Explanation of Plate XVII.

Fig. 10. *Rhynchophorus schach.*
- (a) weevil,
- (b) grub,
- (c) pupa,
- (d) cocoon,
- (e) egg.

Fig. 11. *Oryctes rhinoceros.*
- (a) beetle,
- (b) egg,
- (c) grub,
- (d) pupa.

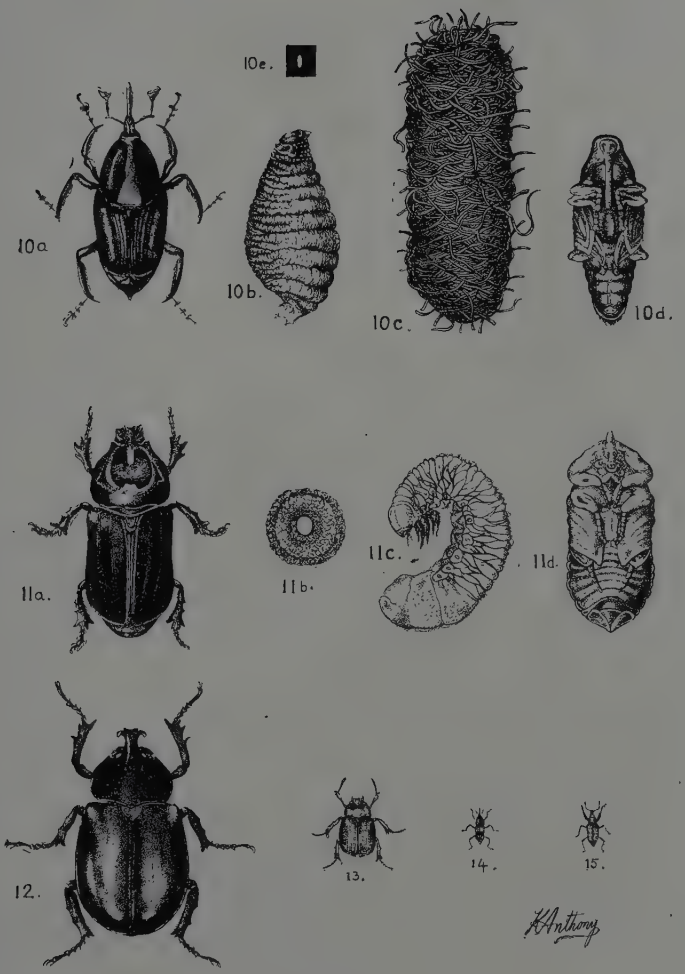
Fig. 12. *Xylotrupes gideon.*

Fig. 13. *Anomala dorsalis.*

Fig. 14. *Diocalandra frumenti.*

Fig. 15. *Trochorrhopalus strangulatus.*

NOTE.—The drawings are slightly less than natural size.



Insect Pests of Oil Palm.

(b) *Insects Recorded, but Causing Insignificant Damage.*

The list below appears formidable, but emphasis must be made of the fact that the names of these insects are published merely for purposes of record. Several have only been observed on the oil palm on one occasion and in no instance has any species caused anything approaching serious injury. With the possible exceptions of *Setora nitens* and *Hidari thrax*, no trouble is expected from any of these insects and these two are especially mentioned because they occasionally cause considerable injury to the coconut palm and might at some future date do damage to the oil palm.

Leaf.—

Setora nitens Walk.	Limacodidae.
Amathusia phidippus L.	Amathusiidae.
Hidari thrax Hübn.	Hesperiidae.
Creatonotus transiens Walk.	Arctiidae.
Xylotrupes gideon L.	Dynastinae.
Anomala dorsalis F.	Rutelinae.
Tambinia capitata Dist.	Tropiduchidae.
Phenice moesta West.	Derbidae.
Oregma nipae de Goot.	Aphididae.
Cerataphis latuniae Boisd.	Aphididae.
Paralecanium expansum Green.	Coccidae.
Pinnaspis buxi Bche.	Coccidae.
Ischnaspis longirostris Sign.	Coccidae.
Aleurocanthus gateri Corb.	Aleyrodidae.

Stem.—

(*Decaying tissue*)

Diocalandra frumenti F.	Curculionidae.
Trochorrhopalus strangulatus Gyl.	Curculionidae.

Flower.—

Orgyia turbata Butler.*	Lymantriidae.
Opogona chalinota Meyr.	Lyonetiidae.
Anatrachyntis centrophanes Meyr.	Cosmopterygidae.
Anatrachyntis falcatella Staint.	Cosmopterygidae.
Anatrachyntis simplex Wals.	Cosmopterygidae.

**Caterpillars similar in appearance to the larvae of Orgyia turbata were found gnawing the female flowers and young fruits of the oil palm. This has only been recorded on one occasion and complaints of similar injury to the fruit bunches have not been received. The other insects on the flowers were bred from dead male flowers.*

Insects have also been bred from the unopened leaves associated with "crown disease", but they are definitely secondary.

MISCELLANEOUS PESTS.

In addition to the insect pests described above there are certain animals, such as rats, wild pig and porcupines, which cause considerable damage, more especially to the young palms by eating the bud. Further, rats are particularly fond of the oily pericarp and will often destroy large quantities of ripening fruit.

Rats.—The rats shelter in the palms and under logs and timber on uncleared areas, although at times they may migrate in large hordes from jungle adjoining the plantation.

When damage from rats is observed in new clearings the young palms can be protected by specially constructed tin shields and also by systematic trapping, but with palms in bearing, especially when the rats are damaging the fruit, the best method is periodical rat hunts.

The best results are obtained by carefully organised trapping, the position of the traps and the nature of the bait being frequently changed. It is also advisable not to handle the traps with the bare hand and to keep them clean and well oiled with a vegetable oil, to which a small quantity of oil of aniseed has been added.

In organising a rat hunt the whole labour force, armed with sticks and accompanied by dogs, is assembled and the rats hunted over a definite area. In addition, the regular destruction of rats by the coolies is encouraged by the offer of a reward of about one cent per tail.

The use of rat virus and of various poisons, such as strychnine, arsenic, phosphorus and barium carbonate is, for several reasons, not recommended on estates.

Pig and Porcupines.—Shooting is the best method of controlling pig and porcupine and on large estates a professional hunter is often employed for this purpose.

VIII.—Harvesting and Yield of Fruit.

Since only ripe undamaged fruit should be collected for treatment in the factory, the questions of both ripening and collection of the fruit will be considered in some detail. Further, since the composition of the fruit changes so rapidly during the final stages of ripening, involving therefore the collection of only ripe fruit if maximum yields of products are to be recovered, details for the average composition of such ripe fruit are given under this heading.

In addition, approximate figures for the yields of fruit from palms of different ages are also included as a guide to the calculation of possible returns of the products which may be expected under normal conditions.

RIPENING OF FRUIT.

The oil palm commences to bear fruit about the third year after planting, but it is not advisable to commence harvesting regularly until about the end of the fourth year.

The bunches of fruit ripen and are usually ready for harvesting within a period of about 5½ to 6 months from the date of pollination, but, if a dry spell prevails during the latter stages of fruit development, this period may be extended for at least another month.

The fruit ripens throughout the year, but the yield is greatest during the months of August and September, during which period the monthly production may be from three to four times that of the lowest yielding months, January and February. This large temporary increase in the yield of fruit must therefore be taken into consideration when selecting plant for the factory.

One of the principal features in the ripening of the fruit is the gradual change in colour, in fact, the colour of the fruit is one of the best indications of the state of ripeness. Immediately after fertilisation the colour of the fruits is light green, but the colour of the parts exposed to the light soon changes to a purple or deep violet, which persists for about 4½ months from the time of pollination. Commencing with the base of the fruit and moving upwards, the colour gradually changes to an orange-red, although the apex of the fruit still retains its dark purplish tint. The parts of the fruits pressed

close together, and those excluded from the light, are of a yellow colour, only those exposed to the light being orange-red in appearance as described above. Immediately these colour changes are completed the fruit may be considered to be mature.

Another indication of ripeness is that the outside fruits in the crown of the bunch become loose. Instances may occur in which only a single fruit can be loosened, while the remainder of the fruits in the bunch are still firmly fixed and remain so for a further few days. The condition of the bunch at this stage must only be taken as an indication of approaching ripeness, the bunch not being considered mature and ready for harvesting until several of the individual fruits can be easily removed.

At this stage also it will be noticed that the hard outside layer of the pericarp, known botanically as the exocarp, will have become comparatively soft.

The importance of harvesting only ripe bunches cannot be emphasised too strongly, since the collection of either unripe or over-ripe fruit will result both in a serious loss in the subsequent recovery of palm oil and in the production of an oil of inferior quality. It is considered advisable at this stage therefore to elaborate these statements, and also to describe briefly the changes underlying the formation of the palm oil in the fruit and the conditions under which the subsequent deterioration of the oil takes place.

For this purpose the fruit may be described as being composed of two parts (*a*) the pericarp, from which is obtained palm oil and (*b*) the nut, containing the palm kernel, from which palm kernel oil is prepared. Palm oil is different in appearance and character from palm kernel oil. It will be seen, therefore, that the important changes taking place are associated with the pericarp of the fruit, those affecting the kernel being only of relatively minor importance.

It is an established fact that in the early stages of development the pericarp contains carbohydrates, a class of chemical compounds composed of carbon, hydrogen and oxygen, to which class of substances both starches and sugars belong. As the ripening process advances the carbohydrate content decreases gradually with a corresponding increase in the oil content. The various changes underlying this conversion of

carbohydrate to oil are not clearly understood, although it would appear that at one stage free fatty acids and glycerol are present and that these react together forming oil. It is significant also to note that there is present in the pericarp a fat-splitting enzyme (non-organised ferment) which, under certain conditions, becomes active and causes decomposition of the oil into free fatty acids and glycerol. This point will be referred to again when describing the extraction of palm oil, since the presence of an excess of free fatty acid in the oil affects its value very considerably.

It has been shown by Blommendaal (13) that the oil present in the pericarp from ripe fruits is practically neutral, the acid value of such oil, calculated as palmitic acid, being approximately 0.5 per cent. Further, the increase in acidity in the case of oil obtained from fruits 5 days after reaching maturity does not exceed 1 per cent.

In view of the tendency of the oil in over-ripe fruits to develop acidity the importance of harvesting only mature bunches will be realised. Further, if the bunches are not gathered when ripe, the fruit is liable to become damaged owing to falling from the bunches. Under these conditions a considerable increase in the free fatty acid content of the oil will result owing to the activity of the fat-splitting enzyme.

Also, from the point of view of oil production the bunches of fruit should not be gathered until ripe. It is well known that the development of oil in the pericarp takes place rapidly during the final stages of ripening and that the oil content only reaches a maximum at maturity.

It is interesting to note that when a bunch has been harvested the production of oil in the pericarp ceases. In this respect the oil palm fruit differs from many other fruits in which the production of an essential constituent of the mature fruit proceeds, even after the latter may have been removed from the plant.

The apparent increase in the palm oil content of fruit stored for a short period is due to loss of moisture in the pericarp, resulting in a diminution in weight of the original fruit on which the calculation should be based. In order that misleading results may not be obtained in factory practice it is essential that the weight of the fruit should be recorded as

soon as possible after leaving the collecting sheds. Figures showing variations in the moisture content of the pericarp will be given later when discussing the composition of the fruit.

Further, if ripe fruits are stored for any period a gradual loss of palm oil takes place, so that fruit should be treated as soon as possible after collection.

HARVESTING OF FRUIT.

In practice it will be found economical to conduct harvesting operations at 5 day intervals, although this period depends upon the productivity of the palms. During the low-yielding months the interval between harvesting operations may be extended to even 6 or 7 days. It will be realised from previous statements that under the former system losses will actually occur as a result of harvesting a proportion of both slightly under-ripe and over-ripe fruits, but it is considered that such losses are more than compensated by the reduced costs of collection.

The present system of harvesting in Malaya is to convey the bunches to collecting sheds situated at frequent intervals throughout the plantation. The bunches are placed on open racks made of bamboo poles, spaced so that the fruits becoming detached fall on to a sloping wooden platform beneath the racks. The bunches are left in these sheds for two or three days, after which they are chopped up and the cleaned fruit despatched to the factory. On large estates light Decauville trucks are used for the transport of the fruit, (see Plate XVIII).

There should be as little delay as possible in conveying the separated fruit to the factory. The fruit is unavoidably bruised to a certain extent during removal from the bunches and, since under such conditions an increase in the free fatty acid content of the oil occurs, it is essential that the interval between the separation of the fruit and the treatment in the factory should be as short as possible.

Under ordinary conditions, one cooly for cutting only the leaf and the fruit bunch and two coolies for transporting the bunches to the collecting sheds can harvest about 160 bunches of fruit per day. It is found impracticable to allot a definite area to a single harvester, more satisfactory results being ob-

Transport of Fruit to Factory.

PLATE XVIII

tained if a gang of about 10 to 15 harvesters, with twice the number of carriers, are allotted an area of about 400 or 500 acres.

The upkeep of a number of collecting sheds scattered over a large estate is expensive, and mention might be made here of a method which has been adopted in Sumatra for dispensing with this arrangement for separating the fruit from the bunches in the field. This method consists in the transport of the whole bunches of fruit direct from the field to the factory, where the fruit is separated mechanically from the bunches. Since this method involves a slight modification of the factory plant at present in use in this country for the treatment of the fruit, it is referred to again in greater detail when describing the preparation of palm oil.

It will now be realised that owing to such rapid changes taking place during the final stages of ripening of the fruit the operation of harvesting must be carefully and expeditiously carried out, otherwise there may be a serious loss in the yield of oil, together with a corresponding reduction in quality owing to a considerable increase in the free fatty acid content of the oil.

COMPOSITION OF FRUIT.

As stated previously, the oil palm fruit consists of an outer pulpy layer, called the pericarp, which contains the oil known as palm oil. The pericarp encloses a small hard-shelled nut, inside which is a kernel, from which palm kernel oil is obtained. The above description is arbitrary and not in accordance with a strict botanical classification, although it is the most convenient method of describing the important parts of the fruit from an economic standpoint.

The bunches of fruit vary considerably in size, those from old palms being larger than those from young palms. The proportion by weight of fruits in the bunch appears to be greater in the case of the small bunches from young palms, although naturally the actual number of fruits in the bunch is much less. In the case of palms about five years old and where artificial pollination is practised, the average proportion of fruit to the bunch is about 60 per cent. by weight.

Marked variations have been found in the composition of individual fruits from different parts of a bunch, for example, inside fruits from a bunch have been found to contain a

higher percentage of oil in the pericarp than the outside fruits. Since the percentage of pericarp in the latter is generally higher than in the former, the percentage oil content, calculated on the weight of the respective fruits from the same bunch, will show little variation.

No attempt is made here to explain such differences in composition, the variations being only of the order expected in dealing with material of such a complex nature as a bunch of oil palm fruit.

Seasonal variations in the composition of the fruit also occur, the oil content of the pericarp increasing slightly during those months when the highest yield of fruit is obtained.

The question of the composition of the fruit will be considered, therefore, from the point of view of average mixed fruit from naturally ripened bunches.

The pericarp constitutes from 57 to 60 per cent. by weight of the ripe fruit, the oil content of the pericarp varying from 48 to 57 per cent. As stated previously, the variations in the percentage of pericarp and its oil content depend both on the degree of ripeness of the fruit and the moisture content of the pericarp. This is shown by results obtained both in Nigeria (14) and Sumatra (15) and is confirmed also by our preliminary investigations.

The moisture content of the fresh pericarp varies from 36 to 40 per cent., but, if the ripe bunches are allowed to remain in the collecting sheds for some days before the separation of the fruit, the moisture content of the pericarp may be reduced to as low as 29 per cent. Attention has been directed previously to the erroneous conclusions which are likely to be drawn regarding the composition of such fruit.

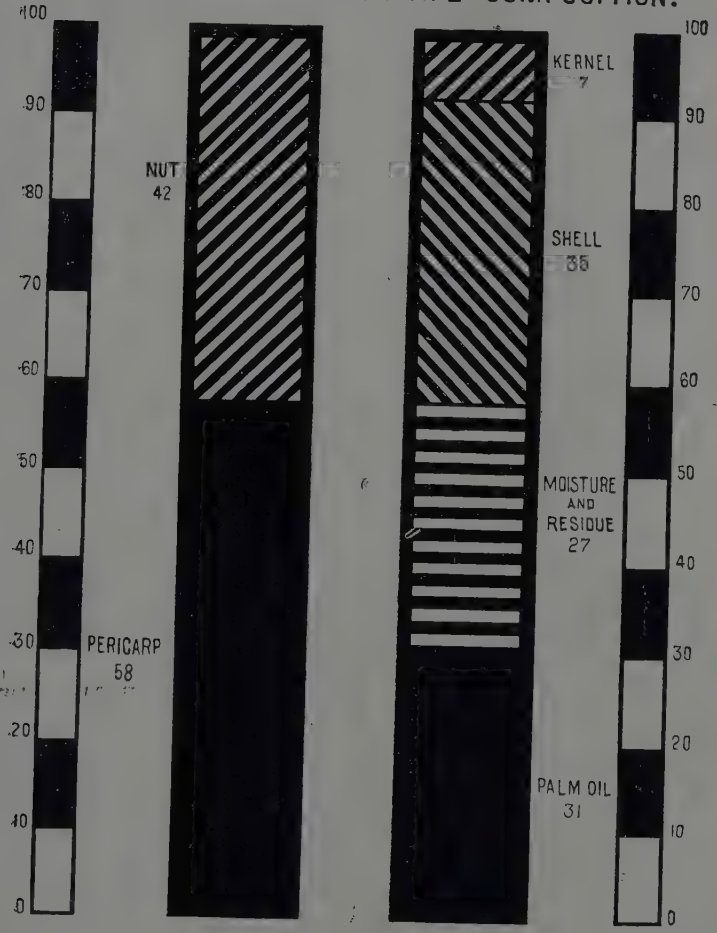
The percentage of palm oil on the ripe fruit has been found to vary from 29 to 32 per cent.

The kernel, which forms the other important constituent of the fruit, and which is exported as such from estates, varies from 6.5 to 8.5 per cent. by weight of the fruit.

The average composition of ripe fruit, collected on the different estates now producing in this country, is given in the following table. These estates are at an early stage of production and are all practising artificial pollination, so that

Composition of Oil Palm Fruit.

Pericarp and Nut. Ultimate Composition.



the figures, which are somewhat variable, can only be taken as a general guide. In each case the sample of fruit examined was taken after delivery at the estate factory.

AVERAGE COMPOSITION OF RIPE FRUIT.

		per cent.
Pericarp		57—60
Nut		40—43
Pericarp	Moisture	29—40
	Oil	48—57
	Residue (by difference)	14—16
Palm Oil (calculated on dry pericarp)		76—80
Nuts, air-dried	Shell	75—82
	Kernel	18—25
Palm Oil (calculated on fresh fruit)		29—32
Kernel (calculated on fresh fruit)		6.5— 8.5

In order to illustrate the above table the average figures for the different constituents, calculated to the nearest whole numbers, are shown in diagrammatic form in Plate XIX.

It must be realised that experimental errors are unavoidable in determining the composition of oil palm fruit, both on account of the difficulty of sampling fruit and pericarp and the impossibility of separating completely the pericarp from the nuts. When large samples of fruit are being treated there may also be a small loss of moisture due to evaporation while the pericarp is being removed.

YIELD OF FRUIT.

Among the principal factors affecting the yield of fruit may be mentioned the age of the palms, the soil conditions under which they are grown, the distance of planting, the height of the plantation above sea level, the intensity of pruning and the seasonal changes which occur during the year. These factors are briefly described below.

During the fourth or fifth year, when the palms have just come into bearing, the tendency is to produce a large number of fruit bunches. At this period an average of 12 to 14 bunches per palm per annum is obtained, but both the bunches and the weight of fruit per bunch are small.

As the palms increase in age (8 to 10 years) the production of bunches is reduced to about 6 or 8 per palm per annum, but the bunches at this stage are about three or four times the size, and the total quantity of fruit produced is approximately double that obtained from the younger palms.

Occasionally palms produce exceptionally large bunches of fruit, which may weigh more than 100 lbs., two illustrations of such bunches being shown in Plate XX. These bunches, which weighed between 90 and 100 lbs. each, were obtained from ten-year old palms.

Soil conditions have a considerable influence on the yield, thus palms planted on a rich alluvial loam will always give higher yields than those on poor sandy or stiff clay soils. Further, palms planted on peaty soil will come into bearing earlier than those on a heavy clay soil. Soil factors must therefore be taken into consideration when making comparisons of yields of palms on different plantations.

The distance of planting is regulated by the soil conditions, palms being planted closer on poor soils than on rich soils. Unless the optimum distance of planting is obtained for a particular type of soil a loss in unit production is certain to result.

The height above sea level may have a considerable influence on the yield but, assuming that both the soil and climatic conditions are suitable, there is no reason to expect any diminution in yield if the palms are planted at an elevation of less than 1,000 feet.

As previously pointed out, another factor which may have a considerable influence on the yield is that of excessive pruning of leaves, but the danger of this practice is now so well known that further comment is unnecessary.

Attention has already been drawn to the effect of seasonal changes on the ripening of the fruit resulting in a consider-

Fruit Bunches Weighing between 90 and 100 lbs. each.

PLATE XX.

able fluctuation in the yield at different periods of the year. During the dry seasons a comparatively low yield of fruit is obtained, but a spell of wet weather following a dry period will hasten ripening, thereby causing a flush of fruit. The result is that during August and September, the commencement of the wet season in Malaya, the monthly yield is approximately double the monthly average over the whole year.

Assuming that the palms come into bearing during the fourth year and that during this period 12 bunches are produced, yielding about 37.5 lbs. of fruit, the yield during the first year of production, allowing for a stand of 55 palms per acre, is equivalent to 2,100 lbs. of fruit per acre.

As the palms become older the number of bunches decreases, but the bunches increase considerably in size. After the tenth year each palm will produce on the average only 6 or 8 bunches annually, yielding approximately 132.5 lbs. of fruit which, with a stand of 55 palms per acre, is equivalent to 7,300 lbs. of fruit per acre.

Taking these figures as a basis and allowing for a recovery of 25 per cent. of oil, calculated on the weight of the fruit, which is approximately the amount obtained in estate factory practice, it will be seen that the production of 2,100 lbs. of fruit in the fourth year is equivalent to approximately 500 lbs. of palm oil per acre, while the production of 7,300 lbs. of fruit in the eleventh year is equivalent to 1,800 lbs. of palm oil per acre.

Further, allowing for a recovery of 6.25 per cent. of kernels, calculated on the weight of fruit, the production of kernels in the fourth and eleventh years will be 150 lbs. and 450 lbs. per acre respectively.

A table giving further details regarding the estimated yields at different ages is given below. In the compilation of this table the following factors have been taken as a basis for calculation—(*a*) number of palms per acre 55 (*b*) proportion of pericarp to fresh fruit 58 per cent. (*c*) yield of palm oil on fruit 25 per cent. by weight and (*d*) yield of kernels on fruit 6.25 per cent. by weight. The figures for the weights of fruit, pericarp and palm oil have been calculated to the nearest hundred pounds in all cases.

Age of Palm.	Fruit per palm per annum.	Fruit per acre.	Pericarp per acre.	Palm Oil per acre.	Kernels per acre.
	lbs.	lbs.	lbs.	lbs.	lbs.
4th year	35-40	2,100	1,200	500	125
5th-6th year	70-75	4,000	2,300	1,000	250
7th-8th „	100-105	5,600	3,200	1,400	350
9th-10th „	115-120	6,500	3,800	1,600	400
After 10th year	130-135	7,300	4,200	1,800	450

The above is considered a conservative estimate of the probable yields under normal conditions taken over a large area. Considerably higher yields will probably be obtained for individual fields, or even throughout a plantation, where the soil conditions are above the average.

Since there are only few palms more than 10 years old growing under estate conditions in this country, it is not possible to state with any degree of accuracy the period during which the maximum yield will be maintained. Evidence at present available on the life of the oil palm can be drawn only from ornamental palms, of which there are several examples known to be more than 50 years old.

IX.—Extraction of Palm Oil and Palm Kernels.

INTRODUCTORY.

On oil palm estates in the East, as in the case of the palms in West Africa, the two products for export are palm oil and palm kernels.

With regard to palm oil, the methods adopted on estates in this country have as their objective the preparation of an oil of low acidity, containing approximately 3 per cent. of free fatty acids. Palm oil of this quality can be used in the preparation of edible fats, although so far the use of the oil for this purpose has been limited by the small quantity of high grade oil available.

The preparation of an oil of this low acidity necessitates modifications of the native processes in use in West Africa for the extraction of the oil. One process consists in heaping the fruit, allowing it to soften by fermentation and, after separation of the nuts, in treating the pericarp with varying quantities of water in order to liberate the oil from the pulp. The oil is separated from the water by heating the liquid and skimming the surface. The oil thus obtained is further heated in order to coagulate mucilaginous matter and to remove all moisture, thus purifying the oil. The oil obtained by this process is known as "Hard" oil, so called from its consistency. Such an oil may contain from 20 per cent. upwards of free fatty acids, which increase during storage.

A second process consists in boiling the fresh fruit with water, after which the mass is pounded and the nuts are separated. The pericarp is then treated with boiling water, the separation of the extracted oil and water being carried out as described above. The oil obtained by this method of extraction is known as "Soft" oil and, if ripe fruit has been selected, the free fatty acid content of such an oil approximates to that of the oil produced in this country.

The essential features of the process adopted in Malaya, are (*a*) the use of only ripe undamaged fruit, (*b*) the sterilisation of the fruit before treatment in order to destroy the naturally occurring enzyme, which is responsible for the development of free fatty acids, and (*c*) the extraction of the oil as rapidly as possible.

SMALL SCALE EXTRACTION OF PALM OIL.

In the early producing stages, when dealing with a comparatively small crop, the fruit on arrival at the factory is sterilised by boiling for about half an hour in water contained in covered circular iron pans. A long brick and cement flue is constructed on the ground and a number of pans is set in a row on top of the flue, each pan being heated by a separate fire.

The sterilised fruit is then pressed in hand screw presses, of which the usual type consists of a perforated steel cylinder, into which a ram attached to a screw is forced. About 25 to 30 pounds of fruit can be treated in one operation. The pressure exerted is insufficient to crack the nuts.

After this first pressing, the fruit is pounded in a mortar by means of a long wooden pestle; the pericarp is detached from the nuts by this treatment and is then separated by hand. In the separation of the nuts a certain proportion of pericarp adheres to the nuts and is thus lost. Samples of shells extracted with a solvent have yielded between 4 and 5 per cent. of palm oil, calculated on the weight of the nuts. This amount is equivalent to approximately 2 per cent. of oil, calculated on the fruit.

The pericarp is then placed in an iron pan, heated by means of boiling water contained in another pan placed beneath and over the fire. The object of this method of steam-heating is to avoid the absorption of water by the pericarp.

The heated pericarp is then wrapped in sacking, pressed again as described above and, in some cases, is heated again and pressed a third time, after which the residue is dried and used as fuel.

The expressed oil, which contains both water and mucilaginous matter, is heated in circular iron pans in order to evaporate the water and coagulate the mucilage, which collects as a scum on the surface and is removed by a ladle. The period of heating is determined by the appearance of the oil, which gradually becomes clear. The oil is allowed to

cool and is skimmed again before filtering through fine cloth into storage tanks, barrels or tins ready for despatch.

The subsequent treatment of the nuts for the recovery of the kernels is described under the heading—"Extraction of Palm Kernels", see p. 362.

In the above process it is possible to produce palm oil of low acidity, although, on account of the improvised nature of the plant and the fact that all the operations are performed by hand, the efficiency of the process is liable to a certain amount of variation. As far as can be judged, the recovery of oil under the best conditions of working is approximately 65 per cent. when the pericarp is pressed twice, while up to 75 per cent. may be obtained by pressing three times. Assuming that the palm oil content of the fresh fruit is about 30 per cent. these recoveries are equivalent to 19.5 per cent. and 22.5 per cent. of oil respectively, calculated on the weight of fresh fruit.

The following table shows figures for average analyses of both fresh pericarp and pericarp residues obtained by this process:—

	Fresh Pericarp.	Pericarp pressed twice.	Pericarp pressed three times.
	per cent.	per cent.	per cent.
Moisture	36.3	44.6	46.3
Oil	49.5	28.4	19.5
Residue (by difference) ...	14.2	27.0	34.2
Oil (calculated on dry material)	77.7	51.3	36.3

MECHANICAL EXTRACTION OF PALM OIL.

When the estate reaches a certain stage of production it is uneconomical to continue the small scale methods of extraction described above and the installation of machinery is essential. At the present time in the East there are two distinct methods for the mechanical extraction of the oil. In Malaya the centrifugal system has been adopted, while in Sumatra the press system is used. The solvent method of extraction, which is the only other method of treating oil-

bearing materials on a large scale has, so far as is known, been adopted on two estates in Sumatra, but only as a subsidiary to the press system.

CENTRIFUGAL SYSTEM.

The centrifugal system is comparatively modern as applied to the extraction of oil from oil-bearing materials and has not been used so far for any other oil seed, possibly on account of the fact that a high proportion of moisture is essential for its successful working. In the treatment of oil seeds the introduction of a large proportion of moisture is undesirable, since in practically every case both the oil and the residue are utilised. The centrifugal system would appear therefore to be limited in its application to those materials, such as oil palm pericarp, which are rich in oil and readily softened with water.

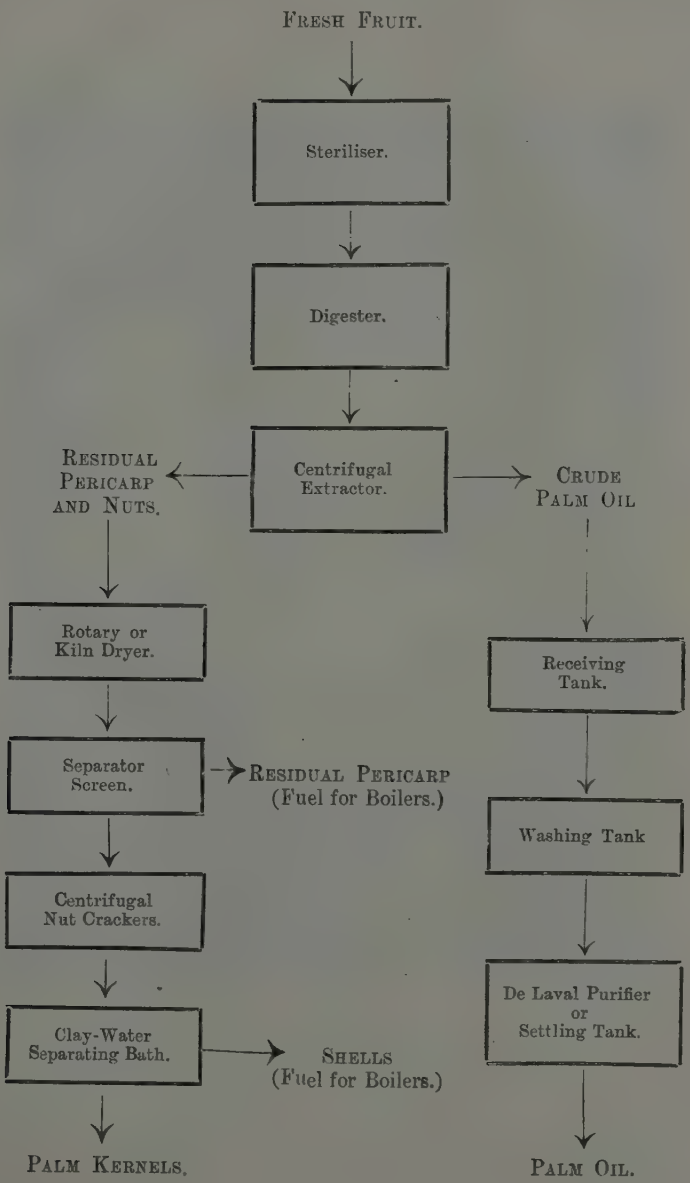
The first plant in operation for the treatment of oil palm fruits by the centrifugal system was exhibited in 1924 at the British Empire Exhibition by Nigerian Products, Ltd. with machinery constructed by Messrs. Manlove Alliott and Co., Ltd., Nottingham. Demonstrations of the plant with West African palm fruit were given at regular intervals during the Exhibition.

Machinery of this type has been supplied to various oil palm estates in this country, and, although centrifugal oil palm machinery by other makers is also in use, the description of the plant given in this section refers more particularly to that exhibited originally at Wembley, modified to suit local requirements.

Briefly, the method consists in a preliminary sterilisation of the clean fruit, followed by a digestion under slight steam pressure. The heated mass of fruit is then discharged into centrifugal extractors rotating at high speed, by means of which the oil is separated. The residue of pericarp and nuts is removed for separation of the nuts and extraction of the kernels.

The sequence of operations involved in the treatment of the fruit by this system is illustrated diagrammatically in the chart on the next page.

TREATMENT OF OIL PALM FRUIT BY CENTRIFUGAL METHOD.



As previously mentioned, the present practice on estates in Sumatra is to despatch the bunches direct to the factory where they are first sterilised, the fruit being separated by means of a special threshing machine. In addition to dispensing with collecting sheds and separation of fruit in the field, this treatment ensures that the fresh ripe fruit is sterilised at an early stage before any bruising, which causes an increase in the free fatty acid content of the oil, can take place.

Although this method involves the transport of approximately double the amount of material to the factory as well as sterilisers of increased capacity, its adoption in Malaya is a matter for consideration, where the production of a high grade palm oil is such a feature of the industry.

Sterilisation and Digestion of Fruit.—In the original plant the clean fruit was heated under slight steam pressure in a vertically arranged cylindrical steam-jacketed digester, fitted with a central vertical shaft, from which a number of beaters radiate. The digester is closed with a steam-tight cover and provision is made for the admission of steam both to the jacket and the interior of the digester.

The object of this treatment is to sterilise the fruit, thereby destroying the naturally occurring enzyme which causes rapid development of free fatty acid in the oil, and to disintegrate the oil cells of the pericarp. It has been found in practice, however, that this treatment is insufficient to prevent the development of free fatty acid. It appears that the bruising action of the beaters in the digester brings the enzyme in contact with the oil before the temperature is sufficiently high to destroy the ferment, with the result that free fatty acids are produced.

It is necessary, therefore, to carry out a sterilisation of the fruit by maintaining it at an elevated temperature for a short period before digestion, either by immersion in boiling water or by steaming under slight pressure. The latter method is preferable, since it is considered that this treatment facilitates the subsequent cracking of the nuts.

Centrifugal Extractor.

If sterilisation is carried out in boiling water the fruit is placed in wire cages, which are immersed in tanks of boiling water heated by means of live steam.

In addition to the destruction of the enzyme the sterilisation assists in the softening of the pericarp, so that the work placed on the digester is reduced considerably.

The transfer of the fruit from the steriliser to the digester should be effected as rapidly as possible in order to avoid loss of heat.

Although the digester described depends for its action on the effect of steam under slight pressure, satisfactory results have also been obtained with a steam-jacketed open vessel.

The importance of an efficient digestion of the fruit must be emphasised, since the amount of oil recovered, either by centrifuging or expression, depends principally on a satisfactory disintegration of the oil cells in the process of digestion.

The period of digestion can be determined only by experiment. This period must not be prolonged, otherwise excessive emulsification of the oil is produced and may result in an increased amount of impurities to be removed from the oil.

The use of a steriliser and a digester involves two distinct operations in separate apparatus, and a suitable vessel can probably be designed for carrying out both operations, in which the fruit is first sterilised by means of steam under pressure and then digested with the beaters at a lower steam pressure for the required period.

Centrifugal Extraction of Oil.—The sterilised and digested fruit is transferred through a chute to a centrifugal extractor of the "Peg-top" self-balancing type, (see Plate XXI). The extractor contains a loose perforated basket, which can be lifted for the discharge of the exhausted residue by means of a special sling, which hooks on to lugs on each side of the basket, (see Plate XXII). The extractor is closed with a well-fitting lid provided with a jointed steam pipe so that steam can be injected into the mash while the centrifuge is being operated, thereby facilitating the expulsion of the oil.

The centrifugal extractors at present in use are belt-driven and operate at speeds varying from about 700 to 1000 revolutions per minute according to the diameter of the baskets. Steam turbine centrifuges may be found more satisfactory. The period of extraction for a charge is about 15 minutes.

Purification of Oil.—The oil, mixed with a certain amount of water and impurities, flows by gravity to a tank below ground level. The oil is then pumped to a steel tank, in which it is treated with live steam in order to coagulate mucilaginous matter, thereby clarifying the oil. The contents of the tank are allowed to settle and the water removed through a pipe fixed in the bottom of the tank.

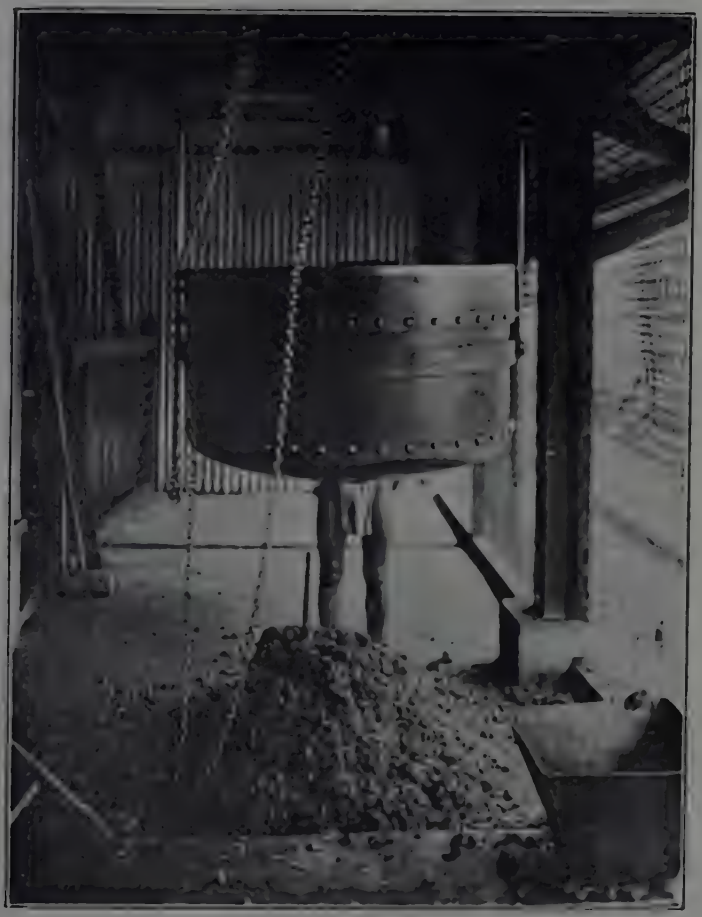
The small amount of sludge, which separates between the water and oil layers, is withdrawn and added to another tank of crude oil. If the quantity is appreciable the sludge must be treated separately by boiling in a tank or pan with water when the oil, which rises to the surface, can be skimmed off.

The purified oil is withdrawn by means of a pipe fixed at a slightly higher level in the tank and transferred to another settling tank, in which it is heated by means of a closed steam coil to allow any moisture or other impurity still present in the oil to settle before filtration through fine cloth into barrels or tins ready for export.

This method of purification is tedious and involves the provision and upkeep of a number of steel tanks, which are liable in time to corrosion owing to the action of the moist oil on the metal. In order to reduce corrosion the oil should be treated as soon as possible after delivery from the centrifugal extractors.

Results of investigations carried out in Nigeria (16) have shown that a satisfactory purification of the oil from sludge and moisture can be effected in a high speed centrifugal machine of the De Laval type. In order to prevent the accumulation of sludge in the machine, which results in frequent stoppages, the oil must first be washed by passing it in a thin stream below the surface of nearly boiling water contained in another tank.

The washed oil, which floats to the surface, is delivered to the centrifugal purifier and from there direct to barrels or other containers for export.



Discharge of Residue from Basket of
Centrifugal Extractor.

The installation of a machine of this type is recommended in order to eliminate the large number of purifying and storage tanks required in the present process.

Quality of Oil.—Using this method, with the precautions described, it is possible to produce palm oil containing approximately 3 per cent. of free fatty acids.

The following table shows figures of average analyses of oil obtained by this process:—

	per cent.
Acidity (calculated as palmitic acid) ...	3.5
Loss on drying at 100° C.	0.3
Solids in suspension	0.01

There is sometimes a slight increase, up to 1 per cent., in the acidity of the oil during transit, which is due to the small quantities of moisture and mucilaginous matter dissolved in the oil.

In order to eliminate these traces the oil should be heated in a tank provided with closed steam coils through which high pressure steam is circulated in order to raise the temperature of the oil above 100°C., thereby coagulating the mucilaginous matter and driving off the last traces of moisture.

Efficiency of Process.—With regard to the efficiency of the centrifugal system, estate factory practice has shown that the percentage recovery of oil from the pericarp is between 85 and 87 per cent. Assuming that the palm oil content of the fresh fruit is about 30 per cent., the recovery calculated on the weight of fresh fruit will be between 25.5 and 26 per cent.

The percentage recovery of oil may rise to 27 per cent. during the months when the highest yield of fruit is obtained. This increase is temporary and is due not to a greater efficiency in the process, but to the seasonal variations in the composition of the fruit.

The following table shows figures for average analyses both of fresh pericarp and pericarp residue obtained by this process:—

	Fresh Pericarp.	Residual Pericarp from Centrifuge.
	per cent.	per cent.
Moisture	36.0	55.0
Oil	50.0	10.0
Residue (by difference) ...	14.0	35.0
Oil (calculated on dry material)	78.1	22.2

In the case of the residue from the centrifugal extractors the oil is almost entirely associated with the fibrous portion, analyses having shown that the amount of pericarp oil adhering to the nuts after sieving is only 0.25 per cent., calculated on the weight of the nuts. This amount is equivalent to approximately 0.15 per cent. of oil, calculated on the weight of fresh fruit.

EXTRACTION OF PALM KERNELS.

Drying of Residue from Centrifugal Extractors.—The residual pericarp and nuts from the centrifugal extractors are conveyed to a rotary dryer. The objects of drying are to reduce the moisture content of the fibrous residue, so that the nuts and fibre can be separated by sieving and to cause the kernels to shrink sufficiently to enable the nuts to be cracked immediately after separation.

The rotary dryer consists of a steel cylinder, inclined slightly to the horizontal and fitted internally with a series of baffle plates so that the material can only travel slowly. The dryer is rotated by means of a cog-wheel fixed on the outside of the cylinder, while the drying is effected by flue gases, from a separate furnace, drawn through the cylinder by a suction fan. Wood fuel has to be used in this furnace on account of the draught induced by the suction fan.

In the present plant the material passes through the cylinder in the same direction as the drying current. This arrangement is unsatisfactory and the efficiency of the dryer could probably be increased considerably by the adoption of

the counter-current principle. It has been stated that there may be a danger of fire with this method owing to the mixture of flue gas and excess air passing over a mass of finely divided material, but in view of the comparatively small reduction in moisture content this objection is not of any serious consequence.

Results of investigations have shown that the moisture content of the fibrous residue after passing through the dryer is between 35 and 40 per cent. Assuming that the moisture content of the material from the extractor is approximately 55 per cent. there is a reduction in moisture content of approximately 35 per cent.

With regard to alternative methods of dealing with the residue, satisfactory results have also been obtained with a kiln dryer similar to that used for drying copra. Such a method has the disadvantage that the material is not conveyed automatically to the separator screen during the process of drying, necessitating therefore the transfer of the material by other means.

Drying and Cracking of Nuts.—The mixture of fibrous residue and partially dried nuts is conveyed to a rotary screen, hexagonal in section and fitted with longitudinal bars which are sufficiently close together to retain the nuts but to allow the fibre to pass between. The screen is slightly inclined to the horizontal, so that the effect of the rotation is to convey the nuts to the lower end, where they are collected for cracking. Although a satisfactory separation of the nuts and fibre is effected, it is not possible to obtain a sufficient shrinkage of the kernel to allow the nuts to be cracked immediately after separation without damage to the kernels. The nuts must therefore be dried in the sun for two or three days or for a shorter period on a kiln dryer. If dried by artificial means, care must be taken to prevent over-heating of the nuts, which causes discoloration of the kernels.

At present the fibrous residue is used as fuel, although it is anticipated that eventually this material will be subjected to solvent extraction for the recovery of the residual palm oil before being used for fuel.

The dried nuts are allowed to cool and treated in centrifugal nut crackers, of which there are two or three efficient types. After cracking, the mixture of kernels, broken shells

and unbroken nuts passes to a screen, on which the unbroken nuts are separated and collected for return to the cracker.

With a plant of large capacity it will probably be advantageous to install two sieves for grading the nuts before cracking, and two nut cracking machines, so that nuts of approximately the same size are always fed to one cracker.

Separation of Kernels.—The kernels and broken shells fall into a bath containing a suspension of clay in water, having a specific gravity of 1.10—1.15, which allows the shells to sink and the kernels to float. The kernels are skimmed off by means of wire baskets, washed in water and dried on cement floors for a few days before being prepared for bagging previous to shipment.

Separation of shells and kernels can also be effected by the use of a brine bath of similar specific gravity. If this method is adopted a centrifugal extractor must be installed to separate adhering brine from both shells and kernels, thereby avoiding loss of salt. The brine bath method has not been introduced into Malaya.

The dried shells are used as fuel. If a brine separation has been used the shells should be washed before being burnt in view of the destructive action of the salt on the furnace or the boiler.

It is essential to dry the kernels before bagging in order to reduce the moisture content, otherwise they become mouldy during transit and, if there are any damaged kernels, there will be an increase in the acidity of the palm kernel oil, (see Plate XXIII).

In the table and diagram showing the average composition of the fruit the proportion of kernel is given as 7 per cent. In practice, the proportion of kernel recovered is usually about 6 per cent., the loss of 1 per cent. representing the loss on drying before bagging.

Kernels dried as described above will still lose slightly in weight during transit.

Neither of the two methods described above for the separation of the kernels is entirely satisfactory. Too many operations are involved in the recovery of a product which is of minor importance. An ideal method is a dry separa-

Sun-Drying of Kernels.

PLATE XXIII

tion, and it is understood that some degree of success has already been obtained in the construction of a machine in which use is made of the difference in shape between kernels and broken shells.

Capacity of Plant.—No mention has been made of the capacities of the various units of which the plant is composed, but it will be realised that the number of the different units and their capacities depend upon the quantity of fruit to be treated. The units comprising the plant are available in various capacities and, as far as possible, the sizes should be so selected that there is no undue delay in any particular part of the process.

The following details are given of the essential parts of the plant required for an area of 2,000 acres in full bearing.

The details of the estimated yields of fruit under such conditions are as follows:—

Weight of fruit per acre per annum	...	3¼ tons.
Total weight of fruit per annum	...	6,500 tons.
Average weight of fruit per day (325 working days)	...	20 tons.

In order to treat the above quantities of fruit it is considered that the following plant will be required:—

Two sterilisers ...	... capacity 1 ton each.
Two digesters ...	... capacity 1 ton each.
Three centrifugal extractors	... capacity 1 ton per set.
Three spare baskets for centrifugal extractors	... capacity 1 ton per set.

The operating periods of the various parts of the plant are assumed to be as follows:—

Period of sterilisation	...	15 minutes.
Period of digestion	...	30 minutes.
Period of centrifuging	...	15 minutes.

The periods allowed for charging and discharging the various parts of the plant are assumed to be as follows:—

Charging of steriliser	... 30 minutes (maximum).
Discharging of steriliser Charging of digester	... 10 minutes.
Discharging of digester Charging of centrifugal baskets	... 5 minutes.
Changing of centrifugal baskets	... 5 minutes

The time-table showing the sequence of the various factory operations is given in tabular form in Appendix—B. It will be seen from this table that with the above plant approximately 18 tons of fruit can be treated in about 8 hours.

In view of the fact that at certain periods of the year the yield of fruit is more than double that obtained at other periods it will be necessary to operate the factory by shifts. This practice is more economical than the installation of a plant capable of dealing with the maximum yield of fruit.

It is not necessary to install the whole of this plant at the outset, although when designing the factory allowance should be made for the necessary extensions.

As far as possible, the various parts of the plant should be so arranged that the operations of charging and discharging the various units involve the minimum amount of labour and transport. For example, the digester should be fixed below the steriliser and the centrifugal extractors conveniently arranged on ground level below the digesters, so that after the fruit has been raised for the first operation it is conveyed by gravity to both the digester and the centrifugal extractor.

No mention is made of the capacity of washing and storage tanks, dimensions of dryer, number of nut crackers and other accessory plant for dealing with the residual pericarp and the nuts, since these portions of the plant can be added as required and represent a minor part of the equipment.

On a large estate, 5000 acres and upwards, a small chemical laboratory should be equipped in which to carry out routine analyses, such as the oil content of the fresh fruit, the oil content of the pericarp residue from the centrifuge and the acidity of the oil.

With an increased production of high grade oil palm products the installation of a laboratory for a large estate or a central laboratory for a group of smaller estates will be essential, since there is little doubt that a high standard of quality will be demanded. In order therefore to maintain the maximum output of such products it will be necessary to pay constant attention to all possible sources of loss in the process and the value of routine chemical control cannot be over-estimated.

It is considered that the capital cost of the factory and plant should not exceed £5—£6 per acre.

At present the selection of the necessary plant and its arrangement in the factory must be left to the initiative of the manager, who should endeavour to select the most efficient types of the various machines and arrange them in the factory so that the treatment of the fruit is completed as expeditiously as possible.

PRESS SYSTEM.

As explained previously, this system for the preparation of palm oil has been adopted with satisfactory results in Sumatra. According to information available the efficiency of the process of pressing the whole fruit is similar to that of the centrifugal system.

Since the press system is so well known in connection with the expression of oil from oil seeds generally a detailed description is unnecessary, although it is advisable to draw attention to certain special features of the process as carried out in Sumatra (17). The principles underlying the preparation of high grade palm oil by the press system are the same as for the centrifugal system.

The method consists in a sterilisation of the fruit bunches, followed by threshing to separate the fruits from the bunches. The fruits are then digested and pressed in a cage-type press. The subsequent purification of the oil is

carried out as described previously. The material from the press is then treated in order to separate the fibrous residue from the nuts, which are then cracked, the kernels being separated as described under the centrifugal system. There is no uniform treatment for the fibrous residue; on one estate it is extracted by a solvent, on some estates it is dried and subjected to a second pressing, while on other estates it is discarded after a single pressing and used as fuel.

On account of the high moisture content of the fruit it is advisable with the press system to carry out the sterilisation of the fruit under slightly increased steam pressure in order to reduce the moisture content of the pericarp and at the same time to coagulate some of the mucilaginous matter present in the fruit, thereby facilitating both the expression of the oil and its subsequent purification.

The best results are said to be obtained if the moisture content of the fruit is reduced to approximately 10 per cent. before pressing. Under these conditions practically no mucilaginous matter is expressed, thereby simplifying the purification of the oil. Such a reduction of the moisture content involves special treatment of the fruit after sterilisation in a vacuum plant, while the digester must be steam-jacketed.

The pressure need not be raised to any great extent when pressing the whole fruit, experience having shown that, provided the fruit has been well digested, the oil is liberated at the comparatively low pressure of $\frac{1}{2}$ ton per square inch. With such a low pressure also there is little possibility of cracking the nuts.

SOLVENT PROCESS.

The solvent process, which appears to be gaining favour for the extraction of oil from oil-bearing seeds, consists in the treatment of the material in large closed extractors with some suitable solvent, petroleum ether, solvent naphtha, benzene or one of the more modern non-inflammable solvents, such as trichlorethylene. The oil dissolves in the liquid and is recovered by evaporation of the solvent.

It is claimed that in the modern process all traces of the solvent can be removed from both the oil and the residue, which is an important factor if the oil is required for edible purposes and the meal as a feeding stuff for livestock. The

solvent process removes approximately 99 per cent. of the oil from the material treated.

Even if the solvent process is not adopted for the fresh fruit, it may prove useful as a subsidiary process for extracting the pericarp, after the fruit has been treated by either the centrifugal or the press system.

DEPERICARPING.

The process of depericarping, formerly regarded as of considerable importance before treatment in either the centrifuge or press, is no longer carried out.

The principal advantage of depericarping is that only pericarp is charged into the centrifuge or press, so that space occupied by the nut, if whole fruit is used, is saved. This allows a greater charge per unit volume of oil-bearing material. On the other hand, depericarping involves an additional operation requiring both labour and power and, as far as is known, a reliable depericarping machine has not yet been devised for continuous operation on a large scale.

Although there is at present no experience in Malaya in respect of the treatment of pericarp in centrifugal extractors, experiments in Nigeria (18) have shown that, if the pericarp alone be charged into the extractor, the material becomes tightly packed thereby preventing the efficient extraction of the oil, which is obtained when the whole fruit is treated.

If a satisfactory depericarper is designed, preliminary sterilisation of the fruit will still be necessary, since free fatty acids will develop to a considerable extent during the depericarping process.

COMPARISON OF PROCESSES.

Three factors require consideration in the adoption of one or other or a combination of the processes described above namely (*a*) efficiency of oil extraction (*b*) capital cost of plant and (*c*) application of the process in the tropics. The third consideration applies more particularly to the solvent process.

Although it is not possible to express a definite opinion on the relative merits of the three processes in their application to oil palm fruit, the following observations are offered.

As stated previously, the efficiency of the centrifugal system compares favourably with the press system.

Although the cost of the units required either for pressing or centrifuging the fruits appears to be approximately the same, the preliminary treatment required in the case of the press system for the reduction of the mucilaginous matter in the expressed oil will add to the capital cost of the plant, so that the adoption of the centrifugal system would appear to be an economic proposition.

Our investigations have shown that more oil can be obtained by pressing the residual pericarp from the centrifugal extractor after the nuts have been separated. It might be advisable, therefore, to install subsidiary presses for treatment of this material similar to the press system, if the maximum efficiency is to be obtained.

In one experiment, approximately 50 per cent. of the oil in the pericarp residue from the centrifugal extractor was expressed, which is equivalent to a further yield of 1.5—2 per cent. of oil, calculated on the fruit.

It is important to note, however, that the moisture content of the residual pericarp must be reduced before treatment in presses. As stated previously, the material from the rotary dryer has a moisture content of 35—40 per cent., which should be reduced to approximately 25 per cent. before pressing. It is understood that if the moisture content is still further reduced the expression of the oil becomes less effective.

On account of the high proportion of fibre and the large reduction in volume when pressure is applied, the satisfactory charging of the press is a difficult matter and, when working on a large scale, it may be advisable to disintegrate the material before pressing in order to secure the greatest efficiency.

No definite information is available in respect of the economics of the solvent process in regard to the most suitable moisture content of the material to be treated, the best type of solvent in relation to the moisture content and the loss of solvent. The last factor is probably the most important in the tropics.

It may be found economical to adopt the solvent process as a subsidiary to either the centrifugal or press system in

order to extract practically all the oil, but the question of the adoption of this process is essentially an economic problem which depends on the value of the oil recovered and the successful application of the process in the tropics.

When considering the possibility of a subsidiary process it is important also to consider the quantity of material available. Assuming the composition of the fruit to be as stated in a previous section and that the main process has resulted in a recovery of 87 per cent. of the pericarp oil, the amount of pericarp residue (10 per cent. moisture content) amounts to only approximately 13.5 per cent. of the original weight of fruit, that is, one ton of fresh fruit yields about 300 lbs. of pericarp residue, containing about 80 lbs. of oil.

In view of the liability of the pericarp residue to develop mould and the importance therefore of treating the residue with as little delay as possible, if high grade oil is to be produced, a subsidiary process is only likely to be successful on large estates of 5000 acres and upwards. In such cases the amount of residue produced is sufficient to maintain a plant in continuous operation and the value of the oil recovered will be in excess of the cost of maintenance.

X.—Packing, Shipping and Marketing.

The questions of packing, shipping and marketing of palm oil are of such importance as to warrant a somewhat detailed description of the general procedure at present adopted. With regard to packing and shipping the present relatively costly methods are only applicable so long as the industry remains on a small scale, and with the anticipated large increase in the exports of oil it is hoped that considerable improvements and economies will be effected.

PACKING AND SHIPPING.

At present the packing charges for the oil form such a large proportion of the cost of production that serious efforts are being made to reduce the expenditure under this heading.

Of the various methods of packing the oil which have been given a trial the use of wooden barrels has given the most satisfactory results and, in spite of its high cost, is the method now adopted in this country, (see Plate XXIV). Barrels made of either English oak or Californian fir appear to be the most suitable, preference being given to the American made barrel for the reason that a large proportion of the palm oil now being produced in Malaya is exported to New York, where a preferential tariff is in favour of the barrel of American manufacture.

The Californian fir, from which the barrels now in use in this country are made, is a hard Douglas fir obtained from the Pacific Coast of the United States of America. The staves are 33¼ inches long by ⅜ inch thick, with bottoms and covers 20 7/16 inches diameter by 15/16 inch thick, and 8 black steel hoops to each barrel.

The staves, bottoms, covers and accessories for a lot of 1,000 barrels, packed separately for export, measure about 50 tons, while the iron hoops weigh about 5 tons. The staves are bundled in stacks, each bundle being tied with 3 stout wires. Each stave is numbered to show the sequence for assembling the barrel. The bottoms and covers are packed in casks to prevent damage, each cask containing sufficient bottoms and covers for 15 barrels.

When the barrels are assembled on the estate it is necessary to treat them inside with hot glue, the latter forming a

Palm Oil Packed for Export.

PLATE XXIV

film on the internal surface of the barrel, thereby preventing absorption of the oil by the wood and minimising the risk of leakage. It is also recommended to paint the barrels outside with a hard drying paint in order to protect the wood.

A finished barrel weighs about 60 lbs. and has a capacity of 40 gallons, equivalent to approximately 375 lbs. of palm oil per barrel. Six barrels are therefore required for every ton of oil produced, so that an estate with an average monthly output of 150 tons of oil requires approximately 11,000 barrels a year.

Although the shipment of the oil in barrels is comparatively satisfactory the method is very costly and, at present rates, the expenditure on packing amounts to nearly one third of the total f.o.b. cost of production. The barrels are assembled on the estate under contract at a fairly cheap rate, but it is the high cost of the materials which is responsible for the heavy expenditure under this heading.

The question of employing locally-grown woods for the construction of barrels has recently been under investigation by the Forest Department in collaboration with the largest producing estate in Selangor. As a result, some trial shipments made to Liverpool showed that of the local woods both "Nyatoh" and "Mersawa" were satisfactory, while "Kapur" was found unsuitable.

The firm of Liverpool brokers, to whom the consignment was forwarded, reported that in their opinion the Nyatoh barrel was a very good package and seemed better than the Californian fir barrels then being sent forward. Further, the Mersawa wood was in every respect similar to the Californian fir.

It is, however, too early to come to any definite conclusions regarding the respective merits of either of the above woods until further trials on a more extensive scale have been carried out. Although the results of the preliminary trials were encouraging, it is now doubtful whether sufficient supplies of the above mentioned woods are readily procurable at a reasonable cost.

Another method of shipping palm oil, which will obviate the use of barrels but which will only be possible when larger quantities of oil are being produced, is bulk-shipment in tank

steamers. Under such conditions the oil would be transported in railway tank wagons, of about 5 to 6 tons capacity, direct to the port of shipment. Such a method would also involve the erection of large steam or electrically-heated tanks, with a capacity of 200 to 250 tons of oil, at the port where the oil could be stored until the arrival of the steamer.

Since palm oil becomes solid in temperate climates it will be necessary to install some form of artificial heating apparatus in the tanks on the steamers in order to facilitate the discharge of the oil at the port of consignment. The heating apparatus should be placed near the bottom of the tanks in order to ensure the complete liquefaction of the oil from the lower layers upwards, the temperature of the oil being raised to about 150°F. before it is discharged.

This method of shipment in bulk is now being considered by a large group of oil palm estates in Sumatra, from where it is understood that several trial shipments on the above lines have already been made with apparently satisfactory results.

The shipping of palm kernels presents no difficulty, the dried kernels being packed in gunny bags.

MARKETING.

The present standards of quality adopted by the trade for buying and selling palm oil are based on what may now be termed a comparatively low grade West African product, since until recent years the world's supply of palm oil was obtained from those parts. For example, in the "Official Contracts for Palm Oil and Shea Butter" issued by the Liverpool United General Produce Association, Ltd., palm oil is classified under different headings, such as "Soft", "Medium" and "Hard", according to the percentage of free fatty acid.

The Official Contract gives the basis of free fatty acids as 18 per cent., calculated as palmitic acid, and states that "any excess of free fatty acids shall be allowed by Sellers, and any reduction shall be paid by Buyers, on the basis of 1s. 9d. per ton for each 1 per cent. over or under 18 per cent. and proportionately for any fraction thereof". Thus, in marketing an oil with an acidity of 3 per cent., such as is now being exported from Malaya, a premium of 1s. 9d. would be allowed for the 15 per cent. reduction of acidity below the standard of 18 per cent., so that the seller would receive 15 x 1s. 9d.,

or £1-6-3 per ton extra, as compared with the price of Lagos "Soft" oil having an acidity of 18 per cent.

This relatively small premium of £1-6-3 per ton for palm oil having a low free fatty acid content, which is based on the standard of the native prepared oil shipped to Liverpool from Africa, is not commensurate with the extra expense involved in the production of such a high grade product prepared under plantation conditions.

The plantation product is now being sold principally on the specification of buyers, who offer a higher price than the prevailing rate for Lagos oil, after including the premium mentioned above. It is understood that a comparatively large proportion of the oil produced in the East is being sold on such lines, principally in New York, which must therefore now be regarded as one of the principal markets for plantation palm oil.

Although the acidity of the palm oil now being exported from this country is between 3 and 4 per cent., there should be no difficulty, with improved factory practice, in reducing this figure to less than 2 per cent. It is not expected, however, that there will be any great demand for oil of such a superior quality until estates are in a position to maintain regular shipments on a large scale.

In order to establish a firm market for a high grade oil, such as can be obtained under plantation conditions, it is considered that the estates concerned should now form some kind of organisation with the object of producing and maintaining a standard product, containing not more than 4 per cent. of free fatty acids. At present, such an organisation could arrange to ship the oil in a standard type of barrel and later, when the output is sufficient to warrant bulk-shipment, the supply of tank wagons and the erection of receiving tanks at the port of shipment can be undertaken.

XI.—Uses of Oil Palm Products.

PALM OIL.

Palm oil varies in colour from orange-yellow to deep orange according to the colour of the original fruit. In the tropics the consistency of the oil varies from a semi-liquid to a hard solid according to acidity, the hardness increasing with the acidity. Palm oil of low acidity, 3 per cent of free fatty acids, will separate on standing into a solid and a liquid fraction, the colour of the solid fraction being much lighter than that of the liquid.

If required for either edible purposes or for the manufacture of high class soap, the oil requires to be bleached.

Bleaching can be carried out in various ways, the usual method employed being to pass a current of air through the heated oil. A large amount of the oil is still bleached by chemical means, such as treating with a mixture of potassium bichromate and hydrochloric acid.

Further, the characteristic sweetish odour of the oil is difficult to destroy and requires treatment with superheated steam in vacuo in order to remove the odoriferous constituents. Such treatment is, however, only necessary if the oil is to be used for special purposes in which the odour would affect the quality of the final product.

The particular application which palm oil finds in industry depends principally upon the acidity of the oil.

Palm oil of low acidity can be used not only in the manufacture of edible oils and fats, but it also forms an excellent basis for the preparation of vegetable butters. As explained previously, the amount of high class palm oil available is small, so that its application in this respect is limited.

At present the oil is used chiefly in the soap and candle industries, the high melting point of the free fatty acids (47°—50°C.) rendering it particularly suitable in the latter industry.

Mention might also be made of the application which palm oil finds in the manufacture of tin-plate. This oil is non-drying, that is to say, it shows no tendency to absorb oxygen when heated and to become thickened. It is there-

fore used to preserve the surface of the heated iron sheet from oxidation, before the sheet is dipped into the bath of molten tin. Palm oil of relatively low acidity, 5 to 7 per cent. of free fatty acids, should be used, since an excess of acid in the oil is liable to corrode the metal.

Palm oil is also used in the manufacture of heavy greases, such as wagon grease and axle greases for locomotives.

The oil has been used as a fuel for internal combustion engines with satisfactory results, although the consumption is slightly greater than that of crude oil. Its application for this purpose would depend chiefly on the relative cost of crude oil.

PALM KERNELS.

Although at present no palm kernel oil is being produced in this country, the kernels being exported as such by estates, brief reference might be made to the applications in industry of palm kernel oil.

The oil is obtained from the kernels either by treatment in hydraulic presses or by solvent extraction, the residual cake or meal being utilised in the manufacture of feeding stuffs for livestock.

Palm kernel oil is semi-solid at the temperature prevailing in the tropics and varies in colour from white to pale yellow. Unlike the pericarp oil the kernel oil is not liable under ordinary conditions to develop a high degree of acidity.

The oil resembles coconut oil in its composition, and high grade oil can be used therefore similarly to coconut oil in the preparation of vegetable butters and so-called "chocolate fat". In the manufacture of the latter product the refined oil is separated into two fractions, a hard white fat known as "palm kernel stearine", and a liquid fraction known as "palm kernel oleine". The solid fraction is used for confectionery purposes and the liquid in the manufacture of soap.

Large quantities of the oil are used directly in the soap-making industry, while the refined oil also has a limited application in pharmaceutical and toilet preparations.

XII.—Values and Returns.

VALUE OF PRODUCTS.

As stated previously, the two oil palm products at present exported from this country are palm oil and palm kernels. Although palm kernel oil can be extracted from kernels it is unlikely that its production will ever be undertaken locally, since it is found more convenient to ship kernels than the kernel oil and cake. Further, the treatment of the palm kernels and the disposal of the oil and cake can be carried out more effectively in Europe, where there is always a steady demand for these two products. No mention will therefore be made of the respective values of either palm kernel oil or palm kernel cake.

Palm Oil.—The palm oil now being produced in Malaya has an acidity of between 3 and 4 per cent., while West African oil may have an acidity as high as 25 per cent. for "Soft" oils and up to 60 per cent. for "Hard" oils. It is difficult, therefore, to compare the values of palm oil with such widely varying degrees of acidity, even taking into account the small premium of 1s. 9d. per unit allowed to plantation oil for each 1 per cent. of acidity below the standard rate of 18 per cent. Unfortunately, however, the quantity of high grade plantation palm oil available on the home market is so small that it is not possible to obtain quotations, so that the only basis on which its present value can be assessed is that of the relatively low grade West African product. It is confidently anticipated that when larger and regular supplies of high grade palm oil are available the latter will command a price comparable with other high grade edible oils, such as coconut oil and groundnut oil.

With the present Liverpool quotations (September, 1927) for Lagos softs between £32 and £33 per ton, and the addition of a premium of £1-6-3 for a reduction of 15 per cent., in the free fatty acid content, the Liverpool market price for plantation palm oil would be therefore between £33-6-3 and £34-6-3 per ton, c.i.f. Liverpool.

A different procedure is adopted on the New York market, where the price is fixed according to the buyers' speci-

fications, although the principal factor determining the price of the oil is the degree of acidity. At the present time the price of plantation palm oil, with a free fatty acid content not exceeding 5 per cent., is about £35 per ton, c. i. f. New York.

The present market quotations for palm oil are somewhat lower than usual, the fall in price being due to a temporary excess of other vegetable oils on the market, particularly cotton seed oil. It is expected that after this surplus has been absorbed there will be a tendency for the oil to return to its former level of between £38 to £40 per ton.

Palm kernels.—On account of the steady demand the price of palm kernels does not show any great fluctuation, being usually about £20 per ton. The present quotations (September, 1927) for kernels on the Liverpool market are between £19-10-0 and £19-12-6 per ton, c.i.f. Liverpool.

ESTIMATED RETURNS.

The principal factors, which must be taken into consideration in estimating the possible returns from the cultivation of oil palms on a plantation scale, may be summarised as follows:—

(1) The capital cost of bringing the estate into full bearing.

(2) The average yield of palm oil and kernels per acre per annum.

(3) The "all in" cost of production of both palm oil and kernels.

(4) The market values of the two products.

The cost of bringing an oil palm estate into full bearing will vary according to the type of land and the locality in which the estate is situated, but under normal conditions the estimated capital outlay should not exceed £45 per acre. This figure is based on an estate of about 2,000 acres fully equipped with proper transport facilities, plant and machinery and all the necessary buildings.

Although an area of about 2,000 acres is considered the minimum unit which can be worked economically by a company it is possible for a private individual, with no overhead charges, to obtain satisfactory results from a much smaller area, provided suitable markets can be found for the products.

It is estimated that under suitable soil conditions an estate in full bearing should give an average yield of approximately 16 cwts. of palm oil and 4 cwts. of palm kernels per acre per annum. This estimate is conservative and it is probable that under the most favourable conditions these yields will be exceeded.

The cost of production will depend chiefly on an adequate supply of suitable labour, not only for the general upkeep of the estate but also for harvesting and collecting the fruit. In this connection it may be mentioned that the number of coolies required for all estate operations will average about one cooly for every 4 to 5 acres in bearing, which is approximately the same figure as that usually allowed for a rubber or coconut estate.

Assuming that a plentiful supply of cheap labour is available it is estimated that the "all in" cost of production should not exceed £25 per ton for palm oil and £10 per ton for palm kernels. These costs are considered liberal and, allowing for the heavy expenditure on packing the palm oil combined with the present high rate for freight charges on this product, the possibility of reducing expenditure in this direction should not be overlooked.

In order to form an estimate of the possible returns from an estate in full bearing, the price of plantation palm oil may be taken as £35 per ton and that of palm kernels as £20 per ton, c. i. f. European or American ports.

Taking the above figures as a basis for calculation, namely (*a*) an annual yield of 16 cwts. of palm oil and 4 cwts. of kernels per acre (*b*) an average "all in" cost of production of £25 per ton of palm oil and £10 per ton of kernels and (*c*) a selling price of £35 per ton for palm oil and £20 per ton for kernels, the estimated annual profit per acre will be as follows:—

Oil Palm Plantation in Malaya.

PLATE XXV

Annual Yield.

16 cwts. of palm oil @ £35 per ton	=	£28-0-0	
4 cwt. of palm kernels @ £20 per ton	=	4-0-0	£32-0-0

Cost of Production.

16 cwts. of palm oil @ £25 per ton	=	£20-0-0	
4 cwts. of palm kernels @ £10 per ton	=	2-0-0	£22-0-0
Annual profit per acre	=		£10-0-0

These figures indicate that, even after allowing for a moderate estimate of the annual yield and a liberal estimate for the cost of production, there is a margin of profit of £10 per acre per annum. Thus, on a capitalisation of £45 per acre, the amount considered necessary to bring an estate into full bearing, an annual profit of £10 per acre is equivalent to a return of approximately 22 per cent. on the capital outlay.

BIBLIOGRAPHY.

(1) Kew Bulletin of Miscellaneous Information, 1889, p. 259.

(2) Beccari, O.—Contributo alla Conoszenza della Palms a Olio. L'agricultura Coloniale (Firenze), Vol. VIII, 1914, pp. 5-37; 108-118; 201-212; 255-270.

(3) Kew Bulletin of Miscellaneous Information, 1914, pp. 285-288.

(4) Bücher, H. and Fickendey, E.—Die Oelpalme, Berlin, 1919.

(5) Annet, E.—Le Palmier à Huile au Cameroun et en Afrique Tropicale, Paris, 1921.

(6) Rutgers, A. A. L.—Investigations on Oil Palms, A.V.R.O.S. Medan, N.I., 1922, pp. 9-11.

(7) Rutgers, A. A. L.—Investigations on Oil Palms, A.V.R.O.S., Medan, N.I., 1922, p. 25.

(8) Curtler, E.A.—Experiments on the Germination of African Oil Palm Seeds, Malayan Agricultural Journal, Vol. XIV, No. 4, April, 1926, pp. 84-87.

(9) Milsum, J.N.—Hastening the Germination of Oil Palm Seeds, Malayan Agricultural Journal, Vol. XV, No. 3, March, 1927, pp. 82-84.

(10) Lambourne, J.—A Preliminary Report on Tapioca as a Catch-crop with Oil Palms, Malayan Agricultural Journal, Vol. XV, No. 4, April, 1927, pp. 104-113.

(11) Rutgers, A. A. L.—Investigations on Oil Palms, A.V.R.O.S., Medan, N.I., 1922, p. 47.

(12) Rutgers, A. A. L.—Investigations on Oil Palms, A.V.R.O.S., Medan, N.I., 1922, p. 53.

(13) Blommendaal, H.N.—Preliminary Paper on the Ripening of Oil Palm Fruits, Communications from the General Experimental Station of the A.V.R.O.S., General Series, No. 20, 1925, p. 13.

(14) Barnes, A. C.—Chemical Investigations into the Products of the Oil Palm, Special Bulletin of the Agricultural Department, Nigeria, 1924, p. 9.

(15) Blommendaal, H.N.—Preliminary Paper on the Ripening of Oil Palm Fruits, Communications from the General Experimental Station of the A.V.R.O.S., General Series, No. 20, 1925, p. 30.

(16) Barnes, A.C.—Mechanical Processes for the Extraction of Palm Oil, Second Special Bulletin of the Agricultural Department, Nigeria, 1925, pp. 20-26.

(17) Blommendaal, H.N.—The Preparation of Palm Oil, Communications from the General Experimental Station of the A.V.R.O.S., General Series No. 21, 1925.

(18) Barnes, A.C.—Mechanical Processes for the Extraction of Palm Oil, Second Special Bulletin of the Agricultural Department, Nigeria, 1925, p. 33.

APPENDIX—A.

CONDITIONS FOR ALIENATION OF LAND.

The terms and conditions now approved by the Federated Malay States Government for the alienation of country land, exceeding ten acres, for the cultivation of oil palm in the Federated Malay States are:—

1. Premium—$3/- an acre or such less sum as the Resident may approve.

2. Rent—50 cents an acre for 6 years and $2/- an acre thereafter.

3. Export Duty—2½ per cent. ad valorem or at such other rate as shall from time to time be notified in the Gazette.

4. Special Condition—The land shall be used solely for the cultivation of oil palm and such catch-crops as are approved by the District Officer.

5. Cultivation Clause—(exceeding 640 acres)—One-quarter of the land shall be cultivated within five years and one-half of the land within ten years from the date of registration of the grant.

6. Food-Crops Clause—(exceeding 200 acres)—That part of the land hereby granted which is edged red on the plan drawn on these presents and has an area of . . . . acres . . . roods . . . . poles more or less shall not be used otherwise than for the cultivation of annual food-crops.

7. Labour Clause—(exceeding 3000 acres)—The proprietor shall on or before . . . . import not less than . . . . labourers from from any place outside the limits of the Malay Peninsula (alternatively from India, from China, from Java, from any place outside the limits of the Federated Malay States, as may be determined at the time of approval of application). Upon proof to the satisfaction of the Resident that the proprietor has fulfilled this condition there shall if the proprietor shall so require in writing be endorsed hereon and signed by the Resident a memorandum to the effect that this condition has been fulfilled and that no further liability attaches to the land in respect thereof.

APPENDIX—B.

PROPOSED TIME-TABLE OF FACTORY OPERATIONS FOR OIL PALM PLANT (*see page 366.*)

Time in Minutes.	Sterilisers.		Digesters.		Centrifugal Extractors.	
	No. 1 (1 ton)	No. 2 (1 ton)	No. 1 (1 ton)	No. 2 (1 ton)	Baskets Nos. 1-3 (1 ton,)	Baskets Nos. 4-6 (1 ton)
0	Charged					
5	↓					
10						
15	Discharged					
20			Charged			
25		Charged	↓			
30		↓				
35						
40		Discharged				
45			↓	Charged		
50	Charged		Discharged	↓		
55	↓				Charged	
60					↓	
65	Discharged					
70			Charged		Removed	
75		Charged	↓	Discharged		
80		↓				Charged
85						↓
90		Discharged				
95			↓	Charged		Removed
100	Charged		Discharged	↓		
105	↓				Charged	
110					↓	
115	Discharged					
120			Charged	↓	Removed	
125		Charged	↓	Discharged		
130		↓				Charged
135						↓
140		Discharged				
145			↓	Charged		Removed
150	Charged		Discharged	↓		
155	↓				Charged	
160					↓	
165	Discharged					
170			Charged	↓	Removed	
175		Charged	↓	Discharged		
180		↓				Charged
185						↓
190		Discharged				
195			↓	Charged		Removed
200	Charged		Discharged	↓		
205	↓				Charged	
210					↓	
215	Discharged					
220			Charged	↓	Removed	

APPENDIX—B. *(Contd.)*

Time in Minutes.	Sterilisers.		Digesters.		Centrifugal Extractors.	
	No. 1 (1 ton)	No. 2 (1 ton)	No. 1 (1 ton)	No. 2 (1 ton)	Baskets Nos. 1-3 (1 ton)	Baskets Nos. 4-6 (1 ton)
225		Charged		Discharged		
230		↓				Charged
235						↓
240		Discharged				
245			↓	Charged		Removed
250	Charged		Discharged	↓		
255	↓				Charged	
260					↓	
265	Discharged					
270			Charged	↓	Removed	
275		Charged	↓	Discharged		
280		↓				Charged
285						↓
290		Discharged				
295			↓	Charged		Removed
300	Charged		Discharged	↓		
305	↓				Charged	
310					↓	
315	Discharged					
320			Charged	↓	Removed	
325		Charged	↓	Discharged		
330		↓				Charged
335						↓
340		Discharged				
345			↓	Charged		Removed
350	Charged		Discharged	↓		
355	↓				Charged	
360					↓	
365	Discharged					
370			Charged	↓	Removed	
375		Charged	↓	Discharged		
380		↓				Charged
385						↓
390		Discharged				
395			↓	Charged		Removed
400	Charged		Discharged	↓		
405	↓				Charged	
410					↓	
415	Discharged					
420			Charged	↓	Removed	
425		Charged	↓	Discharged		
430		↓				Charged
435						↓
440		Discharged				
445			↓	Charged		Removed
450			Discharged	↓		
455					Charged	
460					↓	
465						
470					Removed	
475				Discharged		
480						Charged
485						↓
490						
495						Removed

NOTE.—Total fruit treated = 18 tons in 8¼ hours.